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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXXVI. — *The Radio-Activity of the Salts of Radium;** by BERTRAM B. BOLTWOOD.

THE relation between the α-ray activity of a salt of radium from which all the emanation and the corresponding active disintegration products have been removed and the α-ray activity of the same salt when the total, equilibrium quantity of emanation and active products are present, does not appear to have been previously determined with any great degree of accuracy. According to Mme. Curie,† the maximum activity attained by solid salts of radium after several months is five to six times that which they possess when first separated from a solution. It is stated elsewhere in the same work (p. 116) that when a sample of radium-barium chloride was heated to a red heat, the final, maximum activity was about 1·5 times greater than that attained by the same salt in the normal, crystalline condition, while, in the case of a similar preparation which had been heated to fusion for several hours, the final activity attained a value over twice as great as that ultimately reached by the salt in the form separated from solution. For radium-barium chloride which had been heated to a cherry-red heat for several hours, the activity of the salt immediately after heating was found to be only 16·2 per cent of the activity of the same salt when tested fifty-seven days later (p. 117).

Rutherford and Soddy‡ have also determined the rise in activity of a solid radium salt in the form of a thin film

* The general results and conclusions reached in this paper were presented at a meeting of the American Physical Society held in New York City on February 24, 1906.

† Untersuchung über die Radioaktiven Substanzen. Uebersetzt von W. Kaufmann. Braunschweig, 1904, p. 32.

‡ Phil. Mag. (6), v, 445, 1903.

obtained by the evaporation of a solution from which all emanation had been removed. The activity of the freshly prepared residue from this solution was found to be 25 per cent of the activity of the same residue twenty-one days later.

In none of the papers mentioned are the conditions of experiment shown to be such as to preclude the escape of a portion of the emanation from the material tested, nor do they afford any data on the proportion of the total emanation which was retained by the solid radium compound. Experiments conducted by the writer on uranium minerals* have demonstrated that it is possible for this class of radium compounds to lose at ordinary temperatures very considerable proportions of the radium emanation produced within them.

Since the numerical value of the ratio of the activity of radium itself to the activity of its disintegration products is of considerable importance, and since, moreover, a knowledge of the value of this ratio was essential for the interpretation of other more complicated relations, the following experiments were undertaken in order to determine the relative α-ray activity of radium salts from which all emanation had been removed and the activity of the same salts when the total, equilibrium quantity of radium emanation was retained within them.

Activity of the Salts.

The radium salt used was a weak preparation of radium-barium chloride, having an activity not over 100 times that of uranium. The salt had been prepared about six months previously by chemical operations and repeated recrystallization of the chloride with the object not so much of obtaining a strongly active material as of separating any actinium or polonium which might have been present in the raw material. A few milligrams of this salt were dissolved in 250^{cc} of distilled water to which a few drops of dilute hydrochloric acid had been added. Of this solution exactly 10^{cc} were introduced into a glass bulb by means of a standard pipette, the solution was diluted to about 100^{cc} with water, and the bulb was sealed by fusion. After about sixty days the emanation and other gases in the solution were removed by boiling and were introduced into an air-tight electroscope. The leak after three hours, as indicated by the fall of the gold leaf, was equal to 4·60 scale-divisions per minute. This corresponded to a quantity of radium in solution in the bulb equal to $8{\cdot}5\times10^{-6}$ milligram, or to a content of $8{\cdot}5\times10^{-7}$ milligram of radium in 1^{cc} of the original solution.

A number of very thin films of the radium salt were now prepared by slowly evaporating to dryness 10^{cc} of the standard

* Ibid. (6), ix, 599, 1905.

solution in each of several flat, glass dishes 50^{mm} in diameter and 9^{mm} in depth. The time taken for the evaporation was about three hours, and the salt was deposited in a fairly uniform and extremely thin layer on the bottom of the dish. The freshly prepared films were introduced into an electroscope and their activity measured.

The electroscope in which the solids were measured consisted of an ionization vessel of sheet metal 14^{cm} in height, circular in cross-section, 15^{cm} in diameter at the top and bottom and 19^{cm} in diameter at a point midway between the top and bottom. A circular aluminium plate, 7·5^{cm} in diameter, was supported 9·5^{cm} from the bottom by a vertical, insulated, brass rod, which extended through the top of the ionization vessel and carried a small gold leaf at its upper extremity. This gold leaf was surrounded by a metal case provided with small mica windows. The insulated plate could be charged at will to a potential of about 400 volts from a small storage battery, and the leak of the charge from the plate determined by the fall of the gold leaf which was observed through a microscope with a transparent scale in the eye-piece. The lower half of the ionization chamber could be swung to one side about a pivot without disturbing any other part of the instrument, permitting the placing on the bottom of the ionization chamber of the dishes containing the substances to be tested. When in its normal closed position, the bottom of the ionization chamber was held firmly by three small spring clamps. The entire metal case of the electroscope was electrically connected to earth, as was also the positive pole of the battery. The insulated plate was in all experiments charged negatively.

The initial activity of the films having been determined, they were placed in an air-tight bell-jar over fresh, concentrated sulphuric acid and allowed to remain in this desiccating atmosphere during the intervals between the different measurements. The experiments were conducted during the winter months in a building heated by steam, and measurements were made only on clear, cold days when the atmosphere in the laboratory contained a minimum amount of moisture. When a measurement was to be made, the dish carrying the film was removed from the bell-jar, placed immediately in the electroscope and the measurements carried out as rapidly as possible. The dish was then replaced in the bell-jar and another one removed and measured.

The initial activities of the several films and the activities after the lapse of the stated times is given in the following table in terms of the fall of the gold leaf in divisions per minute. The readings in each case are corrected for the

natural air-leak of the instrument, which averaged 0·038 division per minute.

TABLE I.

Film No.	Initial activity	Activity 3d 22hrs	Activity
1	1·14	3·02	
		12 days	31 days
2	1·20	4·84	5·21
		17 days	
3	1·12	4·60	

When the last measurement given in the table was made, the dish containing the film was quickly placed in the bottom of a small copper can having a capacity of about 300^{cc}. The can was closed with a tight-fitting cover provided with two openings to which were fitted glass tubes. One of these tubes was attached by a short piece of rubber tubing closed with a pinch-cock to the Reichardt apparatus,* and from the other tube, which extended nearly to the bottom of the can, about one-half of the air in the can was exhausted by suction. About 150^{cc} of warm water containing a little hydrochloric acid was introduced through the tube, and the tube was then connected with a flask containing boiling water. A current of steam was passed through the can, and the displaced gases were collected in the Reichardt apparatus. After passing steam for about 15 minutes the accumulated gases were introduced into the air-tight electroscope. The activity of the emanation obtained from the films is given in the following table (Table II) in terms of the fall of the gold leaf in divisions per minute. The percentage of the total emanation present in each film was calculated by dividing the observed leak by the leak caused by the total, equilibrium quantity of emanation corresponding to the amount of radium in the film (4·60 divisions per minute).

TABLE II.

Film No.	Observed leak	Per cent of emanation present
1	1·65	35 9
2	3·29	71·5
3	3·07	66·5

Knowing the length of time which had passed from the time when the emanation had been wholly removed from the salt† to the time when the emanation retained by the film was removed and measured, it is possible to calculate what proportion

* This Journal, xviii, 379, 1904.

† A freshly prepared film was subjected to the same treatment as were the older films, and the complete absence of emanation from the fresh films conclusively proven by experiment.

of the emanation formed from the radium was actually retained by the solid salt. In the following table (Table III) the per cent of the total emanation contained in each film is given in the first column, the per cent of the total emanation which would have been found after the stated time had elapsed, if none had escaped, is given in the second column, and the ratio of these, or the per cent of the emanation actually formed which was retained by the film, is given in the third column.

TABLE III.

Film No.	1.	2.	3.
1	35·9%	50%	71·8%
2	71·5%	100%	71·5%
3	66·5%	95%	70·0%

It is apparent from these numbers that in the films used the radium salt retained only from 70 to 71·8 per cent of the total radium emanation formed within them.

Since the increase in the activity due to the accumulation of definite proportions of emanation and products is given in Table I, it is possible to calculate the activity which the films would have ultimately attained if no emanation had escaped from them. Thus in the case of film No. 1, the difference between the initial activity and the activity at the end of 3 days 22 hours was 1·88. This represents the activity due to 35·9 per cent of the emanation and active products of rapid change. One hundred per cent of the emanation and active products would therefore have an activity of 5·23 div. per minute, and the maximum value of the activity would be 1·14 plus 5·23, which is 6·37. Dividing 6·37, the maximum activity, by 1·14, the initial activity, gives the value 5·59 for the ratio of these two numbers. The corresponding data for all three of the films is given in the following table (Table IV).

TABLE IV.

Number of film	Initial activity	End activity	Per cent of emanation retained	Activity of 100% emanation	Activity if all emanation is retained	Ratio
1	1·14	3·02	35·9	5·23	6·37	5·59
2	1·20	5·21	71·5	5·61	6·81	5·68
3	1·12	4·60	66·5	5·23	6·35	5·67

The average value of the ratio of the activity of the salt free from emanation to the activity of the salt containing all of its radium emanation is, from the above, 5·64.

The increase in the activity of a film of pure radium bromide was also determined by evaporating a solution of pure radium bromide containing a little hydrochloric acid to dryness in one of the glass dishes. The activity of the freshly prepared film

was determined and the dish was then allowed to remain in a desiccator over sulphuric acid for about six weeks. At the end of this period the activity was again determined, and was found to have risen to 3·1 times the initial activity. It is evident that this film retained only about 45 per cent of the emanation formed within it. For the solution from which it was prepared I am indebted to Mr. A. S. Eve of McGill University.

Conclusions.

The ranges in air at atmospheric pressure of the α particles from radium and its disintegration products of rapid change have been determined by Bragg and Kleeman.* The ranges which they found were the following:

1	Radium	3·5^{cm}
2	Emanation or Radium A	4·23
3	Radium A or Emanation	4·83
4	Radium C	7·06

The sum of these numbers is equal to 19·62 and this number is 5·60 times the range of the α particle from radium itself. The value found for the relative ionization or activities of the different products, namely 5·64,† agrees so closely with the ratio of the relative ranges of the same products that it appears highly probable that the α-ray activities of the different products are proportional to the ranges of their α particles. Moreover, since according to the disintegration theory when the parent substance and the products are in radio-active equilibrium the same number of atoms of each are undergoing disintegration per second and the same number of α particles are projected from each exploding atom, it would appear probable that the ionization produced by each α particle is proportional to its range. That the ionization measured was produced almost wholly by the α particles was demonstrated by covering one of the films which had attained its maximum activity with a sheet of aluminium 0·1^{mm} in thickness. The ionization then produced was only about 0·3 per cent of the ionization produced by the bare film.

New Haven, Conn., April, 1906.

* Phil. Mag. (6), viii, 719, 1905.

† The value for the ratio was also determined in an electroscope having an ionization chamber 16^{cm} long, 8·5^{cm} wide and 7^{cm} high. The charged plate, 13^{cm} long and 5^{cm} wide, was suspended 3·5^{cm} from the bottom. The ratio of the activity of the emanation-free salt to the activity of the same substance containing all of its emanation as determined in this smaller electroscope was 5·35, and this lower value is to be attributed to the fact that a portion of the α particles of longer range were stopped by the walls and plate before they had completed their full paths, which resulted in a corresponding reduction in the total ionization.

Art. XXXVII.—*The Radio-Activity of Thorium Minerals and Salts;** by Bertram B. Boltwood.

The radio-activity of the element thorium has been the cause of much discussion and the subject of many apparently contradictory statements in the literature. Following the original announcements by Schmidt† and by Mme. Curie,‡ that the thorium minerals and salts possessed radio-active properties, Hofmann and Strauss published a paper§ in which it was stated that they had separated an inactive thorium compound from a specimen of the mineral euxenite. In a paper by Hofmann and Zerban‖ the claim was later made that an inactive thorium preparation had been obtained from a Brazilian monazite sand, and that thoria separated from bröggerite, cleveite and samarskite, although active when first prepared, had lost its activity some months after its removal from the minerals. Following this in another paper,¶ the same authors claimed to have separated entirely inactive thorium oxide from a specimen of Norwegian gadolinite. It has also been stated by Baskerville and Zerban** that a new source of inactive thorium had been found in a "rock" from South America.

In apparent contradiction to the above we have the statements of Rutherford and Soddy†† that ordinary commercial thorium nitrate and the purest thorium nitrate obtainable gave equal proportions of thorium-X; the statements of Strutt‡‡ that he was able to obtain measurable amounts of thorium emanation from solutions of all of the thorium-bearing minerals, including euxenite and a large number of others, which he tested; and the statements of Mme. Curie and a number of other investigators who had in all cases detected radio-active properties in the thorium minerals which they had examined.

The announcement by Hahn§§ that he had obtained a highly radio-active preparation, from certain residues separated from the mineral thorianite, which was many thousand times more active than ordinary thorium and which gave out

* The general results and conclusions reached in this paper were presented at a meeting of the American Physical Society held in New York City on February 24, 1906.

† Annal. d. Phys., lxv, 141, 1898.

‡ Compt. rend., cxxvi, 1101, 1898.

§ Berichte d. chem. Ges., xxxiii, 3126, 1900.

‖ Berichte, xxxv, 531, 1902.

¶ Berichte, xxxvi, 3093, 1903.

** Jour. Am. Chem. Soc., xxvi, 1642, 1904.

†† Proc. Chem. Soc., xviii, 120, 1902.

‡‡ Proc. Roy. Soc. Lond., A lxxvi, 88 and 312, 1905.

§§ Proc. Roy. Soc. Lond., A lxxvi, 115, 1905.

a proportionately larger amount of the characteristic thorium emanation, appeared at first to add a further complication to the question as to the radio-activity of ordinary thorium salts. Hahn has suggested,* however, that this novel radio-active body, which has been named "radio-thorium," is itself a disintegration product of ordinary thorium. If this hypothesis is correct, it is to be expected that, in the natural minerals containing thorium, the parent substance and its product will have reached a state of radio-active equilibrium and the total activity of the thorium and its products will be proportional to the absolute amount of the element thorium which is present.

The experiments which are described in the present paper were undertaken with the object of determining what proportion of the total α-ray activity of radio-active minerals was produced by the thorium present and whether the activity due to thorium was in all cases proportional to the actual amount of this element contained in the mineral.

Composition of the Minerals.

The minerals used in these experiments were thorianite, thorite, orangite and monazite. The determination of the percentage of thorium oxide in each mineral was carried out in the following manner. The thorianite was dissolved in concentrated nitric acid and the thorite and orangite in dilute hydrochloric acid. The solutions were evaporated to dryness and the residues heated to render the silica insoluble. The residues were then moistened with concentrated hydrochloric acid, boiling water was added and after a short period of digestion the insoluble portions were removed from the solutions by filtration. The filtrates were again evaporated to dryness, the residues treated with a few drops of hydrochloric acid followed by a small quantity of water and the solutions thus obtained were filtered to remove traces of separated silica. The solutions were cooled and diluted, and then treated with an excess of hydrogen sulphide. The precipitated sulphides were filtered off, the filtrates were boiled to remove the excess of hydrogen sulphide, and were poured into boiling solutions containing a considerable excess of oxalic acid. The mixed solutions were then allowed to stand at ordinary temperature and at the end of 24 hours the precipitates of oxalates of the rare earths were collected on filters. The oxalates were converted into nitrates and the excess of nitric acid in the solutions was removed by evaporation. A solution of ammonium oxalate saturated in the cold was prepared and portions of this containing a considerable excess of the salt over the amount necessary to pre-

* Jahrb. d. Radioaktivität, ii, 425, 1905.

cipitate all of the rare earths as oxalates were measured out. These portions of the ammonium oxalate solution were heated to boiling and the dilute, boiling solutions of the neutral nitrates of the rare earths were poured into them with constant stirring. The mixed solutions were diluted with water to twice their initial volume and were allowed to stand in the cold for 48 hours, when the precipitates formed were removed, converted into neutral nitrates and again subjected to the treatment with an excess of ammonium oxalate. The second precipitate of rare earths free from thorium was filtered off, and the two ammonium oxalate solutions were combined, heated to boiling and an excess of hydrochloric acid was added. The solutions were then allowed to stand at ordinary temperatures for 48 hours, the precipitated thorium oxalate was collected on a filter and was ignited to convert the oxalate into oxide.

The finely pulverized monazite was treated with sulphuric acid in a platinum dish. The resulting product was treated with ice water, and the insoluble portion was again treated with sulphuric acid. After removing the part soluble in ice-cold water, the insoluble material remaining was a third time treated with hot sulphuric acid, and a residue amounting to 3·0 per cent of the original mineral remained, which was not further attacked by sulphuric acid. The combined aqueous solutions were made strongly alkaline with ammonia, and the precipitate of phosphates was removed, washed free from sulphates and dissolved in nitric acid. The dilute, nitric acid solution was heated to boiling and poured into a boiling solution containing an excess of oxalic acid. After 24 hours the precipitate of oxalates was removed, the oxalates were converted into chlorides, and the precipitation of the rare earths as oxalates was repeated. The second precipitate of oxalates was converted into chlorides, and to the dilute, boiling solution of the chlorides was added an excess of sodium thiosulphate. The solution was boiled for about 20 minutes until the odor of sulphurous acid could no longer be detected in the steam. The precipitate was then separated from the solution, was treated with hot, dilute hydrochloric acid, the residue of sulphur was removed, and, after the excess of hydrochloric acid present had been largely neutralized with ammonia, the treatment with sodium thiosulphate was repeated. The second precipitate was treated with hot, dilute hydrochloric acid, the chlorides obtained were converted into the neutral nitrates, and the solution of the nitrates was twice treated with an excess of ammonium oxalate in the manner described for thorite and thorianite. The thorium was finally weighed in the form of the oxide. The rare earths were all recovered

from the various solutions which had been obtained in the above series of operations and were reworked for the separation of any thorium which might have escaped the first treatment. Only an insignificantly small amount of thorium was recovered by this second treatment. The residues of sulphur from the precipitates formed by the sodium thiosulphate were also examined for traces of thoria, but with negative results. Exactly 10 grams of monazite was taken for the analysis.

The thorium oxide finally obtained in all cases was perfectly white after intense ignition over the blast lamp.

The percentage of uranium in the minerals was determined in the case of thorianite by direct analysis, carried out by the method which has been previously described.* In the case of the other minerals, and also in the case of thorianite, the uranium present was determined indirectly by comparisons of the amounts of radium emanation produced in the minerals with the amount of emanation produced in a standard, analyzed sample of uraninite.† With the thorianite the results obtained by these two independent methods were in excellent agreement.

Radio-activity of the Minerals.

The radio-activity of the different minerals was determined by a method very similar to that which has already been described by McCoy.‡ The minerals were ground to an impalpable powder with redistilled chloroform in an agate mortar. In the form of a thin paste with chloroform, the powder was then painted with a camel's-hair brush on a thin plate of aluminium. The sheets of aluminium were $7{\cdot}5^{cm}$ wide, 9^{cm} in length and approximately $0{\cdot}1^{mm}$ in thickness, and weighed about 2 grams each. After the chloroform had evaporated it was possible to determine the increase in weight due to the film with considerable accuracy. In order to avoid the necessity of making corrections for the absorption of the rays by the material itself,§ the films were made very thin with a weight of only about 5 milligrams of material on a surface of 60 sq. cm. The errors then due to the absorption of the rays were very small and were within the limit of error of the other measurements. It was found that the activities of films of approximately equal weight prepared from the same material by the above method were in good agreement, and that for films weighing up to 10 milligrams the activities were quite closely proportional to the weight of material taken.

The ionization produced by the films was measured in two different electroscopes, a smaller one having an ionization

* Boltwood, Phil. Mag. (6), ix, 603, 1905.
† Boltwood, loc. cit.
‡ Jour. Am. Chem. Soc., xxvii, 391, 1905; Phil. Mag. (6), xi, 176, 1906.
§ McCoy, loc. cit.

chamber 16^{cm} long, 9·5^{cm} wide and 7^{cm} high, with a charged plate 13^{cm} long and 5^{cm} wide suspended 3·5^{cm} from the bottom, and a larger electroscope with an ionization chamber 15 to 19^{cm} in diameter and 14^{cm} in height, having a circular plate 7·5^{cm} in diameter at a distance of 9·5^{cm} from the bottom. The electroscopes are described in greater detail in an accompanying paper (p. 411).

Calculation of the Thorium Activity.

From the weight of mineral in a given film and the corresponding activity as measured in the electroscope, it is a simple matter to calculate the activity of one gram of the mineral in terms of the fall of the gold-leaf in scale divisions per minute. It has been stated by McCoy* that for uranium minerals containing no thorium, the total activity is directly proportional to the amount of uranium present, and experiments made by the writer on a series of uranium minerals have led to a similar conclusion, provided that corrections are introduced for the amount of radium emanation which escapes from the minerals when in a finely powdered condition. There are therefore two methods available for calculating the activity due to thorium in a series of minerals containing both thorium and uranium. One of these is to determine, from the measurement of a mineral containing uranium only, the activity corresponding to one gram of uranium with its active disintegration products. Knowing this value, it is a simple matter to deduct from the activity of a uranium-thorium mineral of known composition that part of the activity due to uranium and products. If no other radio-active bodies than thorium are present, the remaining activity will be due to thorium and its products only, and on dividing this by the weight in grams of thorium present the activity of thorium per gram will be given. The other method of calculating the activity of the thorium is to solve by algebraic methods the equation obtained through the measurement of two or more unlike thorium-uranium minerals, the equations having the form

$$a\mathrm{U} + b\mathrm{Th} = \mathrm{C},$$

where a is the weight of uranium in one gram of the mineral, b the weight of thorium in the same quantity, and C is the total activity of one gram of the mineral. This second method is only applicable if the activity of the thorium is a constant.

The results as given in this paper were calculated by the first method. The activity corresponding to one gram of uranium and products in a mineral retaining all of its radium emanation

* Phil. Mag. (6), xi, 176, 1906.

was determined for each of the electroscopes,* and after deducting that part of the activity of the thorium minerals due to uranium, the remainder was divided by the weight of thorium oxide per gram of the mineral. The number thus obtained represented the activity of one gram of thorium in the minerals. The general results obtained are given in the table which follows (Table I). The activities are given in terms of the fall of the gold-leaf in the scale divisions per minute. The numbers printed in ordinary type refer to the measurements made in the smaller electroscope, those in italics to the measurements made in the larger electroscope.

TABLE I.

Mineral.	Per cent uranium.	Per cent ThO_2	Activity per gram of mineral. Total.	Due to uranium.	Due to thorium.	Activity per gram of ThO_2.
Thorianite,						
Ceylon	11·2	78·8	85	35	50	63
			153	*59*	*93*	*118*
Thorite,						
Norway	0·4	52·0	34	1	33	63
			62	*2*	*60*	*115*
Orangite,						
Norway	9·4	51·1	63	30	33	64
			108	*50*	*58*	*114*
Monazite,						
N. Carolina	0·35	4·66	4·1	1·1	3·0	64
			7·1	*1·8*	*5·3*	*113*

It will be seen from the numbers given in the last column that the activity of one gram of thorium oxide in the four different minerals varied less than one per cent when determined in the smaller electroscope and not over two per cent from the average when determined in the larger electroscope. This variation is within the limits of error of the several measurements.

It is therefore evident that for the four minerals examined the activity of thorium per gram, or as it will be called, the specific activity of thorium, was a constant. The difference in value between the specific activity as determined in the smaller electroscope is due in part to a greater sensitiveness for the larger instrument and in part to the fact that more complete ionization was obtained in the larger ionization vessel than in the smaller. In the smaller electroscope a portion of the α-particles of longer range are stopped by the walls and charged

* The experimental determination of this factor will be described in a later paper.

plate before they have reached the ends of their free paths in air, as a result of which the maximum ionization is not obtained. This is shown by the value of the ratio of the activities of the films in the smaller electroscope to the activities of the same films in the larger electroscope, which for the thorium minerals was equal to approximately 1·8, while the same ratio for a film of pure uranium oxide was only 1·6. This indicates that the average range of the α-particles from thorium is greater than the average range of the α-particles from uranium.

Radio-activity of Thorium Salts.

In order to determine whether the activity of thorium salts which had been separated from various minerals by different chemical methods was the same per gram of thorium as the specific activity of the thorium contained in the minerals, the following salts were examined:

1. Portion of about 18 grams of pure thorium oxide which had been obtained by working up a quantity of old worn-out incandescent gas mantels obtained from various sources. The mantel dust had been treated with sulphuric acid to convert the earths into sulphates, and the sulphates in dilute solution had been precipitated as oxalates with oxalic acid. The thorium in the oxalates was then extracted by boiling with a strong solution of ammonium oxalate, the solution was greatly diluted and was then allowed to stand in the cold for 48 hours, when the insoluble oxalates were filtered off. The thorium was precipitated as oxalate from the filtrate by the addition of hydrochloric acid to the boiling solution, and the oxalate was converted into oxide by intense ignition over the blast lamp. The oxide thus obtained was pure white.

2. Portion of a quantity (1 kilo) of thorium nitrate obtained from the Welsbach Light Co. A few grams of this nitrate were dissolved in water and the thorium was precipitated as hydroxide, which was then converted into the oxide by intense ignition over the blast lamp. The nitrate had been prepared by the Welsbach Co., by their customary process, from North Carolina monazite sand.

3. Thorium oxide prepared from the same material as No. 2. A portion of the nitrate was converted into the hydrated, crystalline sulphate [$Th(SO_4)_2 . 9H_2O$]. A few small, perfectly clear crystals were selected and converted into the oxide by intense ignition over the blast lamp.

4. A portion of the nitrate mentioned under No. 2 was converted into the anhydrous sulphate. The solution of the sulphate in cold water was heated and a quantity of the so-called

"basic" sulphate of thorium separated. This was ignited to a high heat to form the oxide.

5. Thorium oxide prepared from thorianite by the analytical method described earlier in this paper. The mineral was first dissolved in concentrated nitric acid.

6. Thorium oxide which had been prepared from thorianite. The mineral had been decomposed by fusion with sodium bisulphate and the thorium salts purified by conversion into the double ammonium oxalate as in the case of No. 5 above.

7. Thorium oxide obtained from North Carolina monazite sand by the operations described under the analysis of this mineral.

8. Thorium oxide supplied by Mr. H. S. Miner, chemist of the Welsbach Light Co., and stated by him to have been obtained from monazite sands by the ordinary analytical operations in which the thorium was separated from the other rare earths by repeated precipitation with sodium thiosulphate.

All of the samples of oxides here mentioned had been prepared at least one month previous to the time at which the measurements given in the table were carried out, and all had been subjected to the highest temperature of the blast lamp at the time of their preparation.

TABLE II.

		Activity per gram of oxide.	
Number.	Source of oxide.	Small electroscope.	Large electroscope.
1	Mantel dust	28	50
2	Welsbach nitrate	23	41
3	" "	26	46
4	" "	28	49
5	Thorianite	75	124
6	"	66	116
7	N. C. monazite	63	113
8	Miner's oxide	62	110

The activities of the oxides were determined for thin films in exactly the same way that the activities of the minerals were determined.

It is important to mention the fact that careful attention was given to the question of the emanating power of both the natural minerals and the separated thorium oxides described in this paper. The minerals were chosen particularly because of their low emanating power for both radium and thorium emanations, which was not over one per cent for the highest. Rutherford has shown* that the emanating power of ordinary

* Phys. Zeit., ii, 429, 1901.

thoria is greatly reduced by heating the material to a white heat. The oxides used in the present research were all heated in a platinum crucible to the highest heat of the blast lamp. Quantities several hundred times the weights of the films employed were tested for emanation by placing them in a closed vessel for 24 hours with a plate charged negatively to about 400 volts at a distance of about one centimeter above them. The plate was then tested in the electroscope, but no evidence of an active deposit was obtained. The oxides were therefore essentially non-emanating.

Discussion of Results.

The results obtained from the measurements of the activity of the separated thorium oxides indicate a number of interesting facts with regard to the activity of thorium. The oxides obtained from the commercial thorium salts (Nos. 1 to 4) are uniformly about half as active as the oxides separated from, or contained in, the natural thorium minerals. Since the source of the commercial thorium salts is monazite sand, and since it is shown that the thorium in this mineral and in the salts prepared from it by certain described analytical methods are of normal activity, it is obvious that the chemical treatment to which the commercial salts are subjected results in the separation of about one-half of their radio-active constituents. If it is assumed that the activity of thorium salts is due to the presence of radio-thorium and its disintegration products, then it must be assumed that in the salts of lower activity about one-half of the total radio-thorium present in the mineral has been separated from these salts. From the data given by Hahn* it would appear that in the method of separation by which his radio-thorium was obtained not more than at most two per cent of the total radio-thorium was separated from the mineral. The commercial method of preparing pure thorium salts is therefore much more efficient in effecting the separation of the radio-thorium.†

The fact that the specific activity of the thorium in the minerals was found to be constant is strongly in support of the theory that radio-thorium is a disintegration product of ordinary thorium. It would appear quite impossible to explain the agreement by any other assumption.

* Loc. cit.

† Several pounds of residues obtained from the treatment of monazite with concentrated sulphuric acid were kindly supplied by the Welsbach Company. These residues were examined for the presence of radium and radio-thorium, but with practically negative results for both substances. The amounts of these elements retained in the residues could not have been, at most, more than a fraction of a per cent of the amounts contained in the original mineral.

The data given in this paper has also a direct bearing on the claim made by Hofmann and Zerban* that the activity of thorium in a mineral is dependent on the amount of uranium contained in the mineral. There is a great variation in the uranium content of the two minerals thorianite and thorite, in fact the former contains nearly 18 times as much uranium per gram of thoria as the latter, but as shown in the table the specific activity of the thorium in both minerals is the same. This is also true for the thorium in the orangite and thorite. It is interesting to note that Dr. Zerban was so kind as to send the writer a specimen of 100 grams of gadolinite from Sotersdalen, Norway, supposed to be similar to that examined by Hofmann and Zerban. The mineral was slightly but quite measurably radio-active, was found to give off small quantities of radium emanation (corresponding to about 0·01 per cent U) on solution in acids, and on being worked up furnished a small quantity of thorium oxide of approximately normal activity. The same results were obtained with gadolinite from Llano County, Texas, and the same species of mineral from Ytterby, Sweden. In the published writings of Hofmann and Zerban there is nothing to indicate that any account was taken of the actinium in the minerals with which they worked. This radio-active element invariably accompanies the separated thorium, and in the thorium oxide separated from minerals containing much uranium and little thorium the activity due to the actinium may be much greater than the activity due to the thorium present. Thus, for example, the thoria separated from a sample of North Carolina uraninite, containing 1·5 per cent of ThO_2 and 68 per cent of uranium, was found 40 days after separation to have an activity measured in the smaller electroscope equal to over 550 divisions per minute, or nearly ten times the normal activity. A solution of ten grams of this mineral was, however, examined by Mr. Dadourian, using the excited activity method (see p. 427 of this number), for determining the activity of the thorium in solution, and the activity of the thorium as determined in this manner was found to be normal. All the data available at present point to the conclusion that the amount of actinium in a radio-active mineral is proportional to the amount of uranium in the mineral, and it is the opinion of the writer that the results obtained by Hofmann and Zerban are merely in support of this conclusion and have no direct bearing on the question of the activity of thorium and thorium compounds. In the table on page 422 of this paper (Table II), the high result obtained for the activity of the thorium oxide separated from thorianite (No. 5) is without doubt to be attri-

* Loc. cit.

buted to the presence of actinium in the compound. In the oxide, No. 6, the greater portion of the actinium had been separated from the thorium in some stage of the chemical treatment.

It is important to mention a certain fact with regard to the chemical properties of radio-thorium. Particular emphasis has been laid by Ramsay* on the statement that the oxalate of radio-thorium is insoluble in an excess of ammonium oxalate. It has already been pointed out by Mme. Curie† that the chemical properties of a radio-active element can not be determined with certainty from experiments conducted on a mixture of a small quantity of the active element with very large proportions of a neutral substance. The writer has found this to be particularly the case with actinium, which, when separated from a mineral containing thorium and other rare earths, persistently remains with the thorium through subsequent chemical operations, including the extraction of the thorium oxalate from a mixture of rare earth oxalates by an ammonium oxalate solution, but which, when separated (as "emanium") from a mineral containing no thorium, remains just as persistently with the lanthanum, if this element is present in the original mineral or is added to its solution, and remains undissolved if the lanthanum oxalate is treated with boiling ammonium oxalate solution. Similar conditions appear to hold for radio-thorium, and when accompanied by thorium its oxalate is readily soluble in a solution of ammonium oxalate. The insolubility of the radio-thorium in the thorium-free preparation described by Ramsay can in no sense be considered as indicative of its chemical behavior in an entirely pure condition. In these cases we have probably to do with a peculiar and novel sort of chemical entrainment which is quite distinct from the ordinary processes of solution and precipitation.

It is a very fortunate circumstance that, while the work described in this paper was in progress and before any definite conclusions had been reached, the investigation of the radio-active properties of thorium was quite independently undertaken by Mr. Dadourian, who now presents his results in a paper published in this same number of the Journal. Mr. Dadourian made use of a method which was distinctly different from that of the writer, and which depended on the measurement of the activity of the deposit formed on a negatively charged plate exposed to the emanations escaping from solutions of thorium salts and minerals. The agreement

* Journ. de Chem. Phys., iii, 617, 1905.
† Compt. rend., cxxxii, 273, 1906.

shown in the results obtained by these two independent methods is certainly striking, and would seem to warrant the conclusions which have been reached in the matter. The thorium nitrate from thorianite used by Mr. Dadourian was prepared from the thorium oxide No. 6, mentioned on page 422 of this paper, and the thorium nitrate from North Carolina monazite was prepared from the thorium oxide denoted in the list as No. 7. The fact that Mr. Dadourian's values for the thorium activities of these two preparations are quite independent of any actinium or radium which might have been present, adds a special significance to the numbers obtained by him, as well as to the numbers which he obtained for the other thorium preparations. The agreement of the results obtained by both of us would appear to support the suggestion made by Hahn,* that the disintegration of thorium itself is rayless.

It affords me much pleasure to acknowledge my indebtedness to the Welsbach Light Company, and especially to their chemist, Mr. H. S. Miner, for their great kindness and generosity in supplying me with the greater part of the materials used in these investigations. Their uniform courtesy and liberality has been sincerely appreciated.

Conclusions.

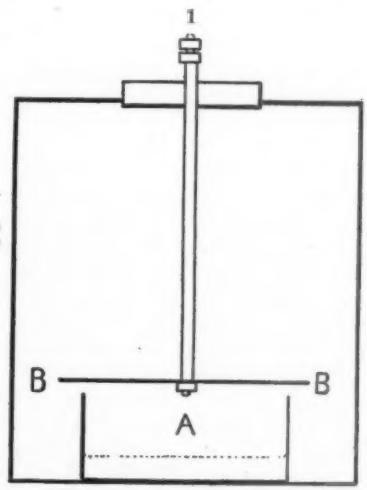
1. The specific activity of thorium with its equilibrium quantities of disintegration products is constant.
2. Radio-thorium is a disintegration product of ordinary thorium.
3. Certain of the ordinary, commercial salts of thorium contain only about one-half of the equilibrium quantity of radio-thorium corresponding to the thorium present.
4. The change undergone by thorium in disintegrating to form radio-thorium is probably rayless.

New Haven, Conn., April, 1906.

* Loc. cit.

ART. XXXVIII.—*The Radio-activity of Thorium;** by H. M. DADOURIAN.

IT has been shown by O. Hahn† that it is possible to separate from thorianite minute quantities of a radio-active substance which is far more active than what is known as thorium. The fact that this substance gives off the same emanation as thorium has led him to suggest that the activity of thorium may be due to the presence in thorium of this substance, which he has named radio-thorium. He has further made the natural supposition that radio-thorium is a disintegration product of thorium. But so far as the writer knows, radio-thorium has not yet been separated from any source except thorianite and no quantitative determinations of the relation between the amount of thorium and its radio-activity has been made, so that the interesting suggestions mentioned above cannot be regarded as fully confirmed.



The following experiments were undertaken in order to determine the quantitative relation between the thorium activity of various minerals and separated salts, and their content of thorium.

The method used is based upon the measurement of the excited activity obtained by exposing a negatively charged body to the emanations evolved by the substance to be tested. The adjoining figure is a sketch of the charging vessels used in these experiments. Each mineral or salt to be tested was dissolved and the solution poured into a flat-bottomed glass dish, A, of 9·5^{cms} diameter and 4^{cms} depth. This was placed in a tin vessel, C, of 15^{cms} diameter and 18^{cms} height, which had a movable cover and could be made air-tight. The body upon which the active deposit was to be obtained was a circular copper plate, BB, of 11^{cms} diameter,

*Read before the American Physical Society, Feb. 24, 1906.

†Chemical News, April 28 and Dec. 21, 1905, Jahrbuch für Radioactivität und Electronik, 1905.

insulated from the tin vessel and connected to the negative terminal of a battery of 400 volts, the other terminal being connected to the tin vessel.

After exposures of 19 hours the copper plates were taken out of the charging vessels and introduced into a testing vessel connected with a Dolezalek electrometer, and the activity observed as usual. Another testing vessel, containing a uranium oxide standard, was connected with the electrometer, in parallel with the first testing vessel, in order to test the sensitiveness of the electrometer during the experiments and allow for changes in the sensitiveness if there were any. The electrometer had a sensitiveness of about 200^{cms} per volt with 100 volts on the needle and the scale at a distance one meter from the mirror.

The emanation generated at a given horizontal layer of the solution has to diffuse through the liquid above that layer in order to reach the surface. Therefore on account of the rapid decay of the thorium emanation (half-value period being 54 seconds) the percentage of the emanation, generated at that layer, which reaches the surface of the solution, will depend upon the depth of the layer. Thus the concentration being the same, the emanation which crosses a square centimeter of the surface per second depends upon the depth of the solution, provided it is not so deep that the emanation produced at the bottom has time enough to decay to a negligible value before reaching the surface, in which case it will be independent of the depth of the solution. The solutions used in these experiments were not deep enough to fulfill the above condition, therefore it was necessary to make all the solutions of the same depth. The equality of depth was realized by putting equal volumes (50^{cc}) of each solution in the flat-bottomed dishes, which were of the same diameter (9·5^{cms}). For similar reasons the negatively charged plates were kept at equal distances from the surface of the solution to which they were exposed.

The solutions tested were of different concentration, therefore in order to be able to compare their activities it was necessary to determine the quantitative relation between the concentration of the solution and the amount of emanation obtained. Two solutions of thorium nitrate were prepared, one of which had a concentration twice as great as the other. Equal volumes of these solutions were placed in flat-bottomed glass dishes of equal diameter, thus securing equal depths. Two copper plates were exposed to these solutions under similar experimental conditions and introduced into the testing vessel. The ionizations produced by the active deposits obtained from the more concentrated and the less concentrated

solutions were found to be 10·9 and 5·4 respectively. These results show that, everything else being the same, the amount of emanation obtained is strictly proportional to the concentration of the solution, as would be expected on theoretical grounds.

The substances tested, chosen on account of their easy solubility, and the results obtained are given in the following table:

Substance.	No. of grams in solution.	Percentage of ThO_2.	No. of grams of ThO_2.	Observed activity.	Specific activity.
I.	II.	III.	IV.	V.	VI.
Thorite	2·00	51·7	1·034	{ 25·7 26·3	{ 24·8 25·4
Thorianite	1·29	76·5	0·987	{ 21·2 25·2	{ 21·5 25·5
Thor. nitrate (1)..	2·20	45·6	1·003	10·7	10·7
" " (2)..	2·15	46·6	1·002	12·5	12·5
" " (3)*.	1·00	38·0	0·38	4·3	11·3
" " (4)..	0·77	48·9	0·376	8·3	22·1
" " (5)..	2·07	48·3	1·00	22·0	22·0

Column I. The thorite was dissolved in dilute hydrochloric acid. The solution was evaporated to dryness, to render the silica insoluble, the silica filtered off and the filtrate diluted in 50^{cc} of distilled water. The thorianite was dissolved in concentrated nitric acid, the solution diluted and a slight residue of insoluble material filtered off. The solution was then evaporated to remove the excess of nitric acid and the remainder diluted to 50^{cc} with distilled water. The thorium nitrates number (1) and number (2) were prepared by the Welsbach Light Co., from North Carolina and Brazilian monazites respectively. Thorium nitrate number (3) was bought from Eimer & Amend about three years ago. Thorium nitrates number (4)† and number (5)† were prepared from North Carolina monazite and from thorianite respectively, by Dr. B. B. Boltwood, to whom the writer is indebted for the minerals and salts tested in these experiments, as well as for their chemical analyses.

Column II gives the number of grams of the substances in the solutions, column III the percentage of thorium oxide in each substance.

In column IV the number of grams of thorium oxide present in the solutions is given. It is obtained by multiplying the numbers of column II by those of column III.

*The percentage of ThO_2 of this salt was not known, therefore it was calculated from the formula $Th(NO_3)_4+12H_2O$. This gives the minimum percentage, hence the calculated specific activity is maximum.

† The process of preparation of these salts is given in a paper by Dr. B. B. Boltwood, in this number of the Journal.

Column V gives, in centimeters per minute,* the average of the ionization produced by the active-deposit measured between 4 and 5 hours after the removal of the potential difference from the negatively charged plate. Some of the substances tested contained more or less radium and actinium. Therefore a comparison of the activities observed during the first few hours, after the removal of the potential difference, could not have been a comparison of the activities due to thorium. But thanks to the rapid rates of decay of the excited activities due to radium and actinium compared with that due to thorium, the activities observed after 4 hours from the removal of the potential difference were entirely due to thorium, the part contributed by radium and actinium having become negligible. Two sets of observations were taken for thorite and thorianite, of which the second set was taken under more favorable experimental conditions. The average observed activities obtained from the first set were 25·7 for thorite and 21·2 for thorianite, while those obtained from the second set were 26·3 and 25·2 respectively.

In column VI the activity per gram of thorium oxide of each substance is given. It is obtained by dividing the numbers of column V by those of column IV. For brevity this will be called the specific thorium activity of the substance.

The agreement between the specific thorium activities of thorite and thorianite is striking, when the difference in nature and origin of these minerals and the experimental difficulties are taken into consideration. On the other hand, there is just as close an agreement among the specific thorium activities of the first three thorium nitrates in the table. Yet there is a marked difference between the specific activities of these two groups, the thorium in the salts being only about half as active as the thorium in the minerals. This difference could not be explained by possible experimental or accidental errors. It was to be accounted for in some other manner. At first it was assumed that thorium might be composed of two or more simple elements of which only one was undergoing radio-active disintegration and giving off the characteristic thorium emanation. According to this, the specific thorium activity will be different for different substances which do not have a quantity of the emanating component proportionate to their content of the remaining components. Thus the difference among the specific activities is accounted for, but the agreement, which is of greater significance, remains to be explained. On account of its improbability and insufficiency this assumption, with some others which will not be considered here, was abandoned in favor of another.

* The spontaneous ionization in the testing vessel was 0·45^{cms}.

According to this hypothesis radio-thorium is a disintegration product of thorium and the producer of thorium X. Thorium emanation being a radio-active product of thorium X, the amount given off by a substance is proportional to the quantity of thorium X present. For a substance in which thorium X and radio-thorium are in radio-active equilibrium, the quantity of thorium emanation given off will be proportional to the amount of both thorium X and radio-thorium but not necessarily to that of thorium present in the substance. If, however, all three, thorium, radio-thorium and thorium X, are in radio-active equilibrium, the proportionality will hold for each of them. All of the substances tested were in radio-active equilibrium as regards thorium X. Therefore the quantity of thorium emanation evolved by any of them should be proportional to the amount of radio-thorium only or to the amount of both radio-thorium and thorium present, according as the latter were or were not in radio-active equilibrium in the substance.

The experimental results given in the above tables follow as natural consequences of this hypothesis. Thus the amount of thorium emanation evolved by the solutions of the minerals should be proportional to their content of thorium as well as radio-thorium, as these are, in all probability, in radio-active equilibrium in the minerals. In other words, the specific thorium activity of the minerals should be the same. This was shown to be the case for the minerals tested, and thorium nitrate number (5), which was prepared from thorianite.

On the other hand, this hypothesis leads to the conclusion that the low specific thorium activity of the commercially prepared salts is due to the loss of part of the radio-thorium in the process of chemical preparation. Therefore, if thorium nitrate salts are prepared from minerals without losing any radio-thorium, their specific thorium activity should be the same as those of the minerals. In order to test this, thorium nitrate number (4) was prepared from 10 grams of North Carolina monazite. The specific thorium activity of this salt was found to be 22·1. This is about the same as the specific thorium activities of thorium nitrate number (5) and the minerals thorite and thorianite. But thorium nitrate number (1), which was prepared from the same mineral (North Carolina monazite), had a specific thorium activity of only 10·7.* The only rational explanation of this great difference in the activity of thorium obtained from the same mineral but by two different analytical methods, is the one just given.

Thus thorium and radio-thorium were in radio-active equilibrium in the specimens of North Carolina monazite from

*Dr. B. B. Boltwood tested these substances by a method described in a paper in this number of the Journal and arrived at similar results.

which thorium nitrates number (1) and number (4) were prepared. No appreciable amount of radio-thorium was lost in the preparation of thorium nitrate number (4). Therefore thorium and radio-thorium were in equilibrium in this salt. This accounts for the fact that its specific thorium activity was about the same as those of the minerals.

About half of the equilibrium quantity of the radio-thorium, on the other hand, must have been separated from thorium nitrate number (1) during the process of its chemical preparation. The few years' time which had elapsed between its preparation from the mineral and these experiments was too short for the thorium and radio-thorium, in the salt, to come into radio-active equilibrium, hence the low specific thorium activity.

The more important conclusions arrived at by the above experiments may be summed up as follows:

First. The amount of radio-thorium in minerals is proportional to the quantity of thorium present. Therefore radio-thorium is a transformation product of thorium.

Second. If thorium and its successive products radio-thorium and thorium X are in radio-active equilibrium in a substance, the amount of thorium emanation evolved by the substance is proportional to the quantity present of any and all of them.

Third. The difference in the specific thorium activities of substances which are in radio-active equilibrium with regard to thorium X, is due to the separation of some of the equilibrium amount of the radio-thorium from the substance.

Fourth. The fact that thorium nitrate number (3), which was prepared over three years ago, was notably deficient in radio-thorium, indicates that the rate of recovery and consequently the rate of decay of radio-thorium is very slow, and that the half-value period cannot be below two years.

In conclusion, I wish to express my hearty thanks to Professor H. A. Bumstead for suggesting these experiments and for the kind interest he has shown during the progress of the work.

Sheffield Scientific School of Yale University,
New Haven, Conn.

ART. XXXIX.—*The Relation between the Radio-activity and the Composition of Thorium Compounds;* by H. N. McCOY and W. H. ROSS.

THE work here described was undertaken with two objects in view. The first was to determine the relation between the radio-activity of thorium minerals and their thorium content, and the second to determine the intensity of radio-activity of thorium, free from its transformation products. The first of these problems was readily solved in a very decisive manner; but the complete separation from thorium of all of its products has proved to be so difficult that we shall not longer delay reporting on the results already obtained.

One of us has shown* that the total activity of any pure uranium compound or of any uranium mineral, free from thorium, is, for each class, proportional to the uranium content of the substance; but that minerals are 4·15 times as active as the pure compounds of equal uranium content. The excess of activity of the ores is due to radium, etc.; and the above results seem to show that all of the radio-active bodies found in thorium-free uranium minerals are transformation products of uranium.

The present study, in a similar manner, of compounds and minerals containing thorium, with or without uranium, forms the natural sequel to the work on uranium. The reports of the interesting work of Ramsay,† Sackur‡ and Hahn§ on the isolation, in a crude state, of a very highly active body, called radio-thorium, from a thorium ore, though they appeared while the present work was in progress, only served to increase the importance of this investigation.

All of the thorium minerals which we have studied contained uranium in measurable, though often very minute, quantities. When the activity due to uranium and its products had been allowed for, the remaining activity, due to the thorium and its products in the mineral, was, in every case, proportional to the thorium content of the sample. The activity due to 1^g of thorium, together with its products, in a mineral, is about 950, the unit of activity being that due to 1$^{sq\ cm}$ of a thick film of uranium oxide, U_3O_8.‖ The activity of pure

* McCoy, Ber. d. chem. Ges., xxxvii, 2641, 1904; Phil. Mag. [6], ix, 176, 1906.

† J. de Chimie Phys., iii, 617, 1905.

‡ Ber. d. chem. Ges., xxxviii, 1756, 1905.

§ Hahn, ibid., xxxviii, 3371, 1905, Radioaktivität, ii, 233, 1905.

‖ The activity of 1^g of uranium in a pure compound is 791, while that of the same quantity of uranium, plus its products, in a mineral, is 3280. 3280=4·15 × 791.

thorium dioxide, ThO_2, resulting from the analysis of thorium minerals, increases with time and reaches a maximum about thirty days after extraction; at the end of this time the activity due to the thorium and products is practically equal to that of an equal mass of thorium contained in a mineral.

Since it has been shown* that radio-thorium, Rt, extracted from a thorium mineral, gives ThX, etc., it would seem almost certain that the following series represents the successive products of thorium, if, as the present work clearly shows, Rt is the product of Th.

$$\mathbf{Th \rightarrow Rt \rightarrow ThX \rightarrow Em \rightarrow ThA \rightarrow ThB.}$$

Rutherford and Soddy† have shown how ThX and subsequent products may readily be removed, and Schlundt and Moore‡ have confirmed and extended these observations. It is an easy task to reduce, by the methods of these investigators as well as by a number of other new methods which we have found equally effective, the activity of thorium to a small fraction of the original value; but within a month practically the whole of the activity is regained. These processes do not appreciably remove radio-thorium, the separation of which from thorium is a difficult matter, and one which we have not yet completely accomplished.

The determination of the radio-activity of thorium compounds is not as simple as in the case of uranium compounds, because the former produce a gaseous emanation, the activity of which is considerable compared with that of the solid film. One of us has shown§ that the total radio-activity of a uranium compound may be determined in two ways. Each of these two ways involves the quantitative measurement of the activity of thin films of the substance, of known weight, varying from about 1 to 20^{mg} per sq. cm. The thickest of such films of all uranium compounds show maximum activity. The total activity of unit weight of a uranium compound is twice the activity due to one surface of an infinitely thin film of unit weight. The activity of such an ideal film is found by graphical extrapolation, for zero weight, of the observed values of the ratio of the weight, w, to the activity, a, of very thin films. The limiting value of this ratio is designated as $\left(\frac{w}{a}\right)_0$. The total activity of unit weight of the compound, $k_1 = 2/\left(\frac{w}{a}\right)_0$. This method may be applied to the compounds of thorium.

* Hahn, loc. cit.
† Phil. Mag. [6], iv, 370, and v, 69, 1902.
‡ J. Phys. Chem., ix, 682, 1905.
§ McCoy, J. Am. Chem. Soc., xxvii, 391, 1905.

Good films of thorium dioxide may be made, as in the case of uranium compounds, using alcohol as the suspending liquid. Critical consideration leads to the conclusion that the emanation produced by a thorium compound must be distributed into three parts; (1) *retained* in the granules of the substance; (2) *emanated* by the granules and *absorbed* by the film; (3) *emanated* by the granules and *evolved* by the film. These three portions of the emanation will be referred to as the *retained*, the *absorbed*, and the *evolved* emanation. Together the *absorbed* and the *evolved* constitute the whole of the *emanated* emanation.

The effect of the evolution of the emanation on the observed activity of the film can be determined theoretically. In the case of a film which has been freely exposed to the open air for at least several hours, the activity due to the film alone is diminished by reason of the loss of emanation. This diminution is due to a deficiency, both of the emanation and of thorium B, the active product of the emanation. The activity of ThB is approximately equal to that of the equilibrium quantity of emanation* and therefore the loss of activity is equal to twice that due to the emanation which has escaped. The activity of a film placed in a small closed space, such as an electroscope case, increases with time and reaches a maximum in about five minutes. The increase of activity is due to the accumulation of the evolved emanation. The activity of this evolved emanation is exactly twice as great as if it had remained in the very thin film, because there is now no absorption of the radiation by the metallic plate, on which the film is deposited. It follows from these considerations that the actual activity of the evolved emanation exactly compensates for the deficiency of activity of the solid film. Therefore *the observed activity of a very thin film of a thorium compound is equal to the true activity.* This relation holds very closely for films of strongly ignited thorium dioxide up to about ·005^{g} per sq. cm. The thorium dioxide, sample A, used in the preliminary measurements was made by heating and finally igniting strongly, in the blast, thorium nitrate made by C. A. F. Kahlbaum. This sample was said to contain ammonia only as an impurity. Its purity otherwise and freedom from non-volatile impurities was established by the analysis of a solution made by dissolving about 4^{g} in 250^{cc} of water. 25^{cc} evaporated to dryness and ignited gave 0·1750^{g} of residue; portions of 25^{cc} diluted and precipitated with ammonia gave upon ignition ·1746 and ·1748^{g}. Finally portions of 25^{cc} gave by Neish's method† ·1751 and ·1754^{g} of pure ThO_2. The

* Rutherford, Radioactivity, p. 307, 1904.
†J. Amer. Chem. Soc., xxvi, 780, 1904.

close agreement of the results of the three methods shows clearly the purity of the sample. The activity of sample A was determined more than a month after preparation; when it had attained a constant (maximum) value.

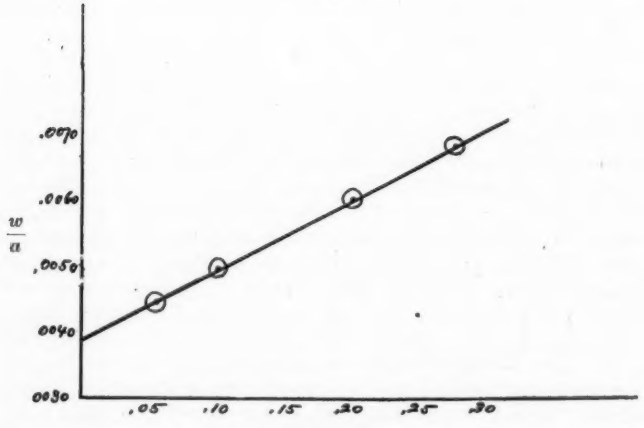
Table I gives the results obtained with very thin films of sample A of thorium dioxide; w is the weight of the film; a is the observed activity of the film, the unit of activity being that due to $1^{sq\ cm}$ of a thick film of pure U_3O_8. The area of each film was $39{\cdot}8^{sq\ cm}$.

TABLE I. THORIUM DIOXIDE—A.

w	a	$\frac{w}{a}$
·2798	41·36	·00676
·2020	30·80	·00599
·1026	20·70	·00495
·0546	12·27	·00444

$$\left(\frac{w}{a}\right)_0 = {\cdot}00387$$

1



Weight, w.

Curve I, which is nearly a straight line, represents Table I. $\left(\frac{w}{a}\right)_0 = {\cdot}00387$. Accordingly k_1, the specific activity of this sample of thorium dioxide, is equal to $\frac{2}{{\cdot}00387} = 517$.

The observed activity of thicker films of thorium compounds must be corrected for the effect of the emanation. To do this the activity of the evolved emanation must be known. This was found as follows: the film was allowed to remain

in the electroscope case for 5 or 6 minutes in order to allow the maximum amount of emanation to accumulate. The electroscope was then charged and as soon as the leaf had reached the beginning of the scale, in the subsequent discharge, the film was rapidly withdrawn from the case, by means of a thread. The small door of the case opened and closed automatically. At the instant of removing the film the position of the leaf on the scale was noted and the stop-watch was started. The leaf continued to move with gradually decreasing velocity for about 5 minutes; at the end of which period the emanation had almost completely decayed and the motion of the leaf had become very slow and uniform, corresponding to the natural leak of the instrument. Calling D the number of divisions of the scale traversed by the leaf in 5 min., corrected for the natural leak, and E the initial activity of the emanation, then $E = \cdot 173\ D$; as shown by the following calculation. Unit activity discharged the electroscope ·075 division per sec. Therefore $\frac{dD}{dt} = \cdot 075 E_t$

$$E_t = E e^{-\lambda t}$$

$$\frac{dD}{dt} = \cdot 075 E e^{-\lambda t}$$

$$D_t = \frac{\cdot 075 E}{\lambda} (1 - e^{-\lambda t}).$$

For the thorium emanation $\lambda = \cdot 013$. If $t = 300$ sec. $e^{-\lambda t} = 0$ practically, and therefore

$$E = \cdot 173\ D$$

E is very small except for the thicker films. Table II gives the results for some thick films of sample A of thorium dioxide.

TABLE II.

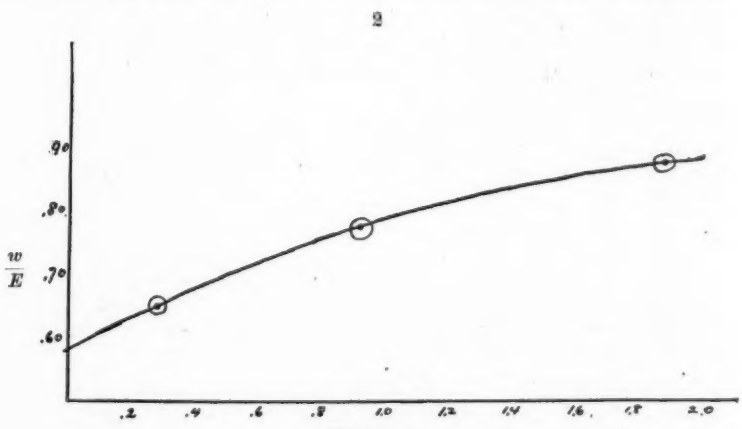
w	E	$\frac{w}{E}$	F
1·8893	2·17	·87	·68
·9182	1·20	·77	·80
·2798	·43	·65	·90

$$\left(\frac{w}{E}\right)_0 = \cdot 58$$

$\left(\frac{w}{E}\right)_0$ represents the value of the ratio $\frac{w}{E}$ for an infinitely thin film, curve II. For such an ideal film of unit weight, the activity of the *evolved* emanation would be $\frac{1}{\cdot 58} = 1 \cdot 71$. This is also the activity of the *emanated* emanation of unit weight

of this sample of thorium dioxide, since there would be no absorption of the emanation by such a film. The fraction emanated, of the whole amount of emanation produced by the sample, can now be calculated. About one-fourth of the activity of ThO_2 is due the emanation.* Therefore the total activity of the whole of the emanation of 1^g of the sample $= \frac{517}{4} = 129$. $\frac{1{\cdot}71}{129} = {\cdot}013$. Therefore 1·3 per cent of the whole emanation is emanated. The last column of Table II gives the fraction, F, of the *emanated* emanation which is *evolved* by the film.

The above results may now be used to correct the observed activity of a thick film. The observed activity, a_1, of a film of



a thorium compound is too great by the amount E, the activity of the *evolved* emanation. But the value $a_1 - E$, which represents the activity of the solid film alone, is too low, because the film has lost a fraction of its emanation and ThB. The lost activity is equal to $2E$ since the activity of the ThB is equal to that of the equilibrium amount of the emanation. The total activity of the film is $k_1 w$. Therefore the true activity of the film is

$$a = \frac{a_1 - E}{1 - \frac{2E}{k_1 w}}$$

Table III gives in column 2 the observed values of the activity, a_1, and in column 3 the corrected values, a. The

* Rutherford, loc. cit.

fourth column contains the values of the ratio, x, of the activity of any film to that of a thick film of maximum activity. $x = \frac{a}{56{\cdot}9}$.

$$k_2 = \frac{2{\cdot}303\, s}{w} \log \frac{1}{1-x}$$

k_2 is the absorption coefficient* and s is the area of each film, $39{\cdot}8^{\text{sq cm}}$.

TABLE III. THORIUM DIOXIDE—A.

w	a_1	a	x	k_2
·0546	12·27	12·26	·216	177
·1026	20·70	20·66	·363	175
·2020	33·80	33·66	·592	177
·2798	41·36	41·0	·721	182
·9182	55·6	54·7	---	---
1·8893	58·8	56·9	---	---
			Mean	178

The specific activity, k_1, of the sample can now be calculated from the absorption coefficient.

$$k_1 = \frac{2k_2 a}{s} = \frac{2 \times 178 \times 56{\cdot}9}{39{\cdot}8} = 509$$

The mean value of k_1, for the two methods, is 513.

Thorium dioxide contains 87·9 per cent of thorium. Therefore the activity of unit weight of thorium, together with its active products in sample A, is $\frac{513}{879} = 584$. The activities of several thorium minerals have been determined by the extrapolation method as worked out for sample A of pure thorium dioxide. The locality of origin and the composition are shown in Table IV.

TABLE IV.

No.	Name.		Per cent Th.	Per cent U.
1	Orangite	Langesundsfjord, Norway	43·1	7·76
2	Thorite	" "	46·6	6·26
3	Monazite	McDowell Co., N. Carolina	5·27	·33
4	"	Roade, Norway	15·18	·46
5	"	Commercial sample	2·72	·12

The analyses for thorium were made by the method of Neish† and for uranium by reduction with zinc in sulphuric acid

* McCoy, J. Chem. Soc., xxvii, 395, 1905.
† Loc. cit.

solution and titration with permanganate* after separation as phosphate by the method of Brearley.†

The activity of films of thorium minerals can be corrected for the effect of the emanation according to the formula applied to films of pure ThO_2. In calculating a from a_1, the approximate value of k_1, as found from the uncorrected activity of the thinner films, was used. This procedure involved no appreciable error.

The results are given in Tables V to IX. The significance of the symbols has already been given. The curves for all the minerals were smooth. It is not necessary to reproduce them here.

TABLE V. ORANGITE, No. 1.

w	a_1	a	$\frac{w}{a}$	E
1·2400	52·29	47·2	·02628	5·8
·3415	45·01	44·1	·00775	1·5
·2259	39·24	38·8	·00583	1·0
·1212	28·46	28·3	·00428	‡(·55)
·0526	14·85	14·8	·00355	(·24)

$\left(\frac{w}{a}\right)_0 = ·00310$ $\qquad$ $\left(\frac{w}{E}\right)_0 = ·22$

TABLE VI. THORITE, No. 2.

w	a_1	a	$\frac{w}{a}$	E
1·1825	50·51	47·1	·02511	3·90
·3243	43·03	42·4	·00765	1·16
·2339	39·37	39·0	·00600	·88
·1349	29·74	29·6	·00456	(·53)
·0904	22·61	22·6	·00400	(·34)

$\left(\frac{w}{a}\right)_0 = ·00301$ $\qquad$ $\left(\frac{w}{E}\right)_0 = ·26$

TABLE VII. MONAZITE, No. 3.

w	a_1	a	$\frac{w}{a}$	E
1·0587	4·70	4·55	·233	·17
·2825	3·96	3·94	·0717	·04
·2059	3·43	3·42	·0602	(·03)
·1094	2·36	2·35	·0466	(·02)
·0476	1·23	1·23	·0387	(·01)

$\left(\frac{w}{a}\right)_0 = ·0332$ $\qquad$ $\left(\frac{w}{E}\right)_0 = 6·2$

* Kern. J. Amer. Chem. Soc., xxiii, 685, 1901; Pulman, this Journal, xvi, 229, 1903.

† Analytical Chemistry of Uranium, 1903.

‡ The values of E in parenthesis are calculated from $E = w \Big/ \left(\frac{w}{E}\right)_0$.

TABLE VIII. MONAZITE, No. 4.

w	a_1	a	$\frac{w}{a}$	E
1·1081	12·83	12·27	·0903	·64
·2973	10·75	10·64	·0279	·17
·2123	9·53	9·48	·0224	·12
·1078	6·26	6·24	·0173	(·06)
·0526	3·68	3·67	·0143	(·03)

$\left(\frac{w}{a}\right)_0 = ·0122$ $\left(\frac{w}{E}\right)_0 = 1·7$

TABLE IX. MONAZITE, No. 5.

w	a_1	a	$\frac{w}{a_1}$	E
1·0590	2·15	a is practically equal to a_1	·493	Too small to be accurately measured
·3174	1·89		·168	
·2156	1·70		·127	
·1375	1·37		·100	
·1170	1·25		·094	
·0785	·89		·088	
·0348	·46		·076	

$\left(\frac{w}{a}\right)_0 = ·067$

In Table X, k_{1m} represents the total activity of 1^g of the mineral as calculated from

$$k_{1m} = 2 \Big/ \left(\frac{w}{a}\right)_0$$

k_{1U} represents the activity due to the uranium and products contained in 1^g of the mineral. This is equal to 3280 times the weight of uranium in 1^g of the mineral, since it has been shown* that the total activity of that quantity of any thorium-free mineral containing 1^g of uranium is 3280 units. k_{1Th} is the difference between k_{1m} and k_{1U}; it represents the total activity, due to the thorium and its products, in 1^g of the mineral. In the last column P_{Th} is the weight of thorium in 1^g of the mineral. $\frac{k_{1Th}}{P_{Th}}$ is as nearly constant as one could reasonably expect, considering that all of the errors of experiment are accumulated on this ratio. The radio- activity of any mineral which is sufficiently old, geologically, is therefore equal to $3280\ P_U + 953\ P_{Th}$.

TABLE X. THORIUM MINERALS.

No.	Name	%Th	%U	k_{1m}	k_{1U}	k_{1Th}	$\frac{k_{1Th}}{P_{Th}}$
1	Orangite ..	43·1	7·76	649	255	394	914
2	Thorite ...	46·6	6·26	664	205	459	985
3	Monazite ..	5·27	·33	60·2	10·9	49·3	935
4	" ..	15·18	·46	164	15	149	982
5	" ..	2·72	·12	29·8	4·0	25·8	950

Mean = 953

* McCoy, Phil. Mag. (6), xi, 176, 1906.

All of the thorium activity measurements, as well as those of uranium compounds and minerals, were made with a distance of 3·5^{cm} between the active films and the charged electrode. While this thickness of air is sufficient to absorb practically all of the alpha rays of uranium, it is scarcely great enough to absorb completely the more penetrating alpha rays of some of the radium and thorium products.* With a greater distance than 3·5^{cm} between the films and electrode a somewhat greater activity will be found for uranium and thorium minerals. The general relationship between the radio-activity and the composition of such minerals having now been fully established, we are starting a new series of measurements on minerals with the object of determining their activities under conditions such that the maximum ionizations due to the alpha rays can take place in the space between the film and the electrode.

In the analyses of the minerals the thorium was weighed as dioxide. This was very pure, chemically. It had been separated by Neish's method, having been precipitated once by oxalic acid, once by potassium hydroxide and two or three times by m-nitrobenzoic acid. The activity measurements of three such samples, B, C, and D, were made from time to time until after about one month the activities had reached constant maximum values. The ThO_2 then contained the maximum amounts of ThX, Em, ThA and ThB. The results of the maximum values are given in Tables XI to XIII with a summary in Table XIV.

TABLE XI. THORIUM DIOXIDE B.

w	a_1	a	$\frac{w}{a}$	E
·2267	61·4	60·9	·00372	1·04
·1170	40·2	40·1	·00292	(·5)
·0673	25·1	25·1	·00268	(·3)

$$\left(\frac{w}{a}\right)_0 = ·00243$$

TABLE XII. THORIUM DIOXIDE C.

w	a_1	a	$\frac{w}{a}$	E
·2634	68·2	67·8	·00389	1·04
·1292	41·8	41·7	·00310	(·5)
·0657	24·1	24·1	·00273	(·2)

$$\left(\frac{w}{a}\right)_0 = ·00230$$

*Rutherford Radioactivity, p. 135, 1904; Bragg, Phil. Mag., viii, 721, 1904; Bragg and Kleeman, Ibid., x, 318 and 600, 1905.

TABLE XIII. THORIUM DIOXIDE D.

w	a_1	a	$\frac{w}{a}$	E
·2088	57·6	57·2	·00365	1·1
·1083	35·9	35·7	·00303	(·6)
·0585	21·6	21·5	·00272	(·3)

$$\left(\frac{w}{a}\right)_0 = \cdot 00240$$

TABLE XIV. THORIUM DIOXIDE.

Sample	Source	$\left(\frac{w}{a}\right)_0$	k_1	$\frac{k_1}{P}$
A	Th Nitrate	·00387	517	588
B	Orangite No. 1	·00243	823	936
C	Thorite No. 2	·00230	870	989
D	Monazite No. 4	·00240	833	948
	Mean of B, C and D..			958

The mean value of $\frac{k_1}{P}$ for the last three samples is 958, while the value of the corresponding ratio for thorium in minerals is 953. From this it follows that none of the radio-thorium has been separated from the thorium by the processes of analysis. However, we have been able by certain other processes, many times repeated, to reduce the permanent activity of thorium considerably below that of sample A, presumably by the removal of part of the radio-thorium, but we have not yet obtained thorium which is, or remains, entirely inactive. We shall discuss this problem fully in a later paper. It is possibly still a question whether thorium, entirely freed from radio-thorium, ThX, etc., will produce rays capable of ionizing gases;* but that it is undergoing transformation, rayless or otherwise, which gives rise to active products, seems certain from the fact that the portion of the radio-activity due to thorium, of any mineral, is directly proportional to the thorium content of that mineral. We believe our experiments also show clearly that the activity of thorium compounds is not due to bodies accidentally retained by thorium (as radium frequently is by barium sulphate), but that the radio-thorium, ThX, etc., are disintegration products of thorium.

Kent Chemical Laboratory,
University of Chicago, April, 1906.

* Inactive or slightly active thorium has been reported several times (Hofman and Zerban, Ber. d. chem. Ges., xxxvi, 3093, 1903; Zerban, ibid., xxxviii, 557, 1905; Baskerville and Zerban, J. Amer. Chem. Soc., xxvi, 1642, 1904; but in such cases no statement has been made of the minimum intensity of activity that could have been detected.

ART. XL.—*Prorosmarus alleni, a new genus and species of Walrus from the Upper Miocene of Yorktown, Virginia;* by EDWARD W. BERRY and WILLIAM K. GREGORY.

DURING a recent excursion of one of the classes in geology of the Johns Hopkins University, one of the students, William E. Curley, Jr., found on the beach at Yorktown, Va.,* a left mandibular ramus of a new extinct mammal evidently allied to, but much more generalized than the existing species of walrus, *Odobœnus rosmarus* and *Odobœnus obesus.* The specimen was presented to the Department of Geology of the University, where it is now deposited under the care of Professor William Bullock Clark, who has generously entrusted it to the present writers for identification and description.

The new genus agrees with *Odobœnus:* (1) in the general characters of the mandible; (2) in the general location of the mental foramen, which is in each case followed by a much smaller foramen; (3) in the cylindrical shape of the cheek teeth. In other characters *Prorosmarus* is much more primitive and approaches the Otariidæ or Eared Seals in the following features: (1) The mature jaw retains two well developed incisors in each ramus as in the young walrus, the adult walrus lacking the incisors. (2) The canine retains its primitive position and caniniform shape, whereas in the walrus the canine has been taken over into the molariform series, as shown by its biting against the molariform outer upper incisor and by its separation from the molariform series in the young jaw. The interpretation of this tooth as a canine in *Odobœnus* was adopted by Flower, Huxley, and J. A. Allen† in the solution of the long vexed question of the homologies of the unique dentition of the walrus. (3) The inner side of the lower canine of our specimen is considerably worn, and hence to judge from the conditions in other Pinnipeds the upper jaw must have retained three functional incisors in the adult. (4) Viewed from the side the whole ramus is less curved downward and the chin and symphysial surface is much more slender and slopes more forward than in *Odobœnus*, but is much heavier and more roundly developed than in the Otaries. The posterior half of the ramus is thus relatively deeper and the anterior half is relatively shallower than in *Odobœnus.* (5) The opposite symphysial surfaces did not be-

*These late Tertiary littoral deposits have been recently recognized by Clark and Miller as distinct from the underlying beds and formally named the Yorktown formation.

†See summary in Allen's "History of North American Pinnipeds." Washington, 1880, pp. 47–57.

come anchylosed as is the case in even the young walrus, but remained separate, although the deeply corrugated surfaces were closely appressed and doubtless firmly bound together by ligament. (6) The coronoid process is relatively higher, more

1

FIG. 1. The type of *Prorosmarus alleni*, lower jaw (left ramus), external view. One-third natural size.

slender and more inclined backward than in *Odobænus*. (7) Viewed dorsally, the opposite mandibular rami rapidly converge to a point opposite the first "molar" when they sud-

2

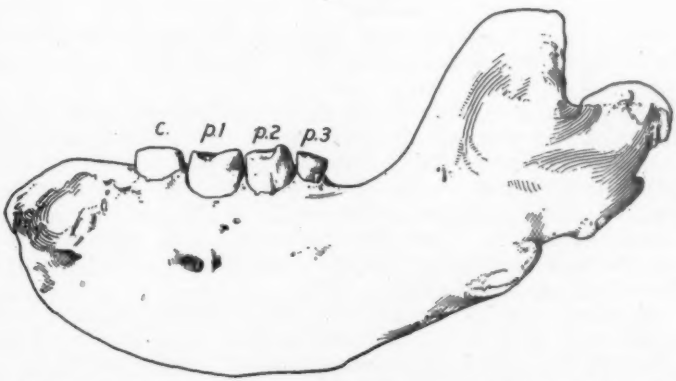


FIG. 2. Lower jaw (left ramus), external view, of an old male Atlantic Walrus (*Odobænus rosmarus*). One-third natural size.

denly expand into a broad spatulate everted lower lip. In cross section this region is broad at the top, narrowing rapidly below (figs. 1, 4A). In *Odobænus*, on the contrary, the rostrum is much compressed above and broadly convex below (figs. 2, 4C). (8) In *Prorosmarus* on the lower border of the jaw below

the second and third "molars" is a prominent rounded protuberance about 4^{cm} long and gradually fading away posteriorly. This protuberance may have furnished attachment for ligaments binding the rami together as well as for the digastric muscle which depressed the jaw. In the modern walrus this process is indicated in the young jaw, but becomes strongly inflected, lengthened, and less conspicuous in the adult. Additional and less important differences from *Odobænus* are as

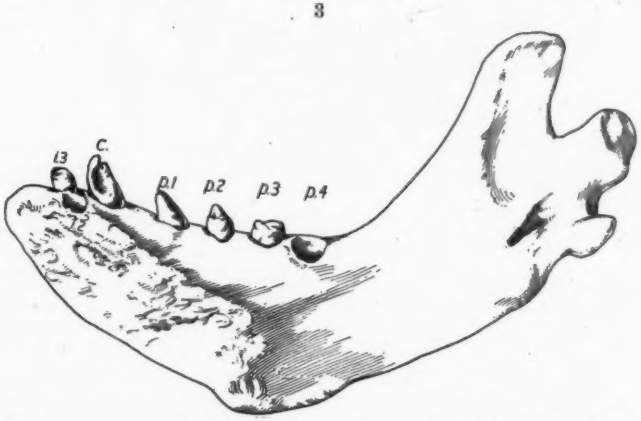


FIG. 3. Type lower jaw (right ramus) of *Alachtherium cretsii* DuBus. Internal view, one-fourth natural size. (After Van Beneden.)

follows: (9) The subequal size of the molariform teeth which in *Odobænus* successively decrease in size, the most anterior (*c*) being the largest. (10) The molars must have been circular in section whereas in the adult walrus they are laterally compressed. The molariform teeth probably also had a somewhat more pointed tip than in *Odobænus*. (11) *Prorosmarus* retained one more fully functional molariform tooth (p_4), which is vestigial or absent in the walrus.

In brief the jaw of *Prorosmarus* seems to be much less specialized than is the modern walrus jaw. In the latter, doubtless in response to the need for an effective crushing apparatus, the distal portion of the jaw has become very massive; the enormous growth of the upper canines has caused the disappearance of the incisors and the transference of the lateral upper incisor and the lower canine to the molariform or cheek series; the effective center of the lower molar series has gradually been shifted forward and the upper molar series have acquired oblique wearing surfaces, so that the shock of impact is partially transmitted to the massive upper canines.

The detailed description of the specimen is as follows:

Prorosmarus alleni gen. et sp. nov.

Mandibular ramus complete except posteriorly, the coronoid process and the region of the mandibular angle being broken off at a point which leaves the inferior dental canal (8mm in diameter) centrally located and on a horizontal line with the alveolar border. The jaw is extremely massive throughout and is vesicular anteriorly and along the alveolar region. The *canine* alone is in place and from its worn appearance indicates an old animal, as does also the character of the whole specimen.

Dental formula.—The *dental formula* of the lower jaw is $I_{\frac{}{2(i_2,\ i_3)}}$, $C_{\frac{}{1}}$, $P_{\frac{}{4(p_1-p_4)}}$, $M_{\frac{}{0}}$, but judging by analogy with the walrus one or more of the true molars may have been present in the young jaw, and even as vestiges, without alveoli, in the adult. It would be interesting to know whether the milk teeth were better developed than in *Odobænus*, as Flower believed that in *Odobænus* the vestigial milk teeth "never cut the gum, but are absorbed rather than shed," this process commencing before birth. In the upper jaw there must have been three incisors (the existence of the outer pair being plainly indicated by the worn antero-internal face of the lower canine), a canine not nearly so much enlarged as in *Odobænus*, four premolars and possibly one or more much reduced molars. The outer lateral incisor, like its opposing tooth the lower canine, had not yet been taken over into the molariform series. Thus the complete dental formula of the adult was probably $I\frac{3}{2}$, $C\frac{1}{1}$, $P\frac{4}{4}$ $M\frac{?}{?}$.

The *internal incisor* (i_2 of the typical Eutherian formula) was evidently considerably reduced in size as compared with the other teeth, but still functional, and was apparently retained in the specimen until after the death of the animal. It is placed almost behind the outer incisor, decumbent, directed forward at an angle of about 45°. Alveolus round, 8mm in diameter and 2cm in depth. The *outer incisor* (i_3) is large, approximately paralleling the canine in direction. Alveolus 13×15^{mm} in diameter, the longest diameter being transverse; depth 5cm.

Canine—Bluntly conical, directed slightly forward and outward and curving slightly backward, nearly circular at the base in cross section but slightly flattened anteriorly. Much worn on the antero internal quadrant, presumably by the attrition of the upper outer incisor. Height 2·2cm, diameter 1·7cm, diastema 1·4cm. The premolars were all rounded, simple and deep-set. The first alveolus indicates a vertical, slightly forward direction and is 1·7cm in diameter and 4·4cm in depth. The second alveolus indicates a slight outward and forward direction and is 1·8cm in diameter and 4cm in depth. The third alveolus is very slightly

inclined backward and is 1·9^{cm} in diameter and 3·8^{cm} in depth. The fourth alveolus indicates a considerable backward inclination of the contained tooth, and is 1·8^{cm} in diameter and 3·2^{cm} in depth. Thus we see a progressive shortening of the alveoli from before backward, but apparently no diminution worth taking into account in the diameter of the teeth for the whole molariform series. There is no indication of an additional molar, which is remarkable, when we consider the large size of the fourth premolar, and indicates that the fifth tooth in the molar series was vestigial or absent.

Anterior mental foramen large. Mandibular symphysis 11^{cm} long and 4^{cm} in greatest height, very massively corrugated throughout. The *muscular attachments* are all strongly marked.

Measurements.

Total length, condyle to incisive border (estimated)	21·5^{cm}
Anterior border of first "molar" (p_1) to posterior border of coronoid (estimated)	17
Breadth of coronoid at base	2·1
Horizontal diameter of coronoid at base	4·5
Length of molar series	8
Antero-posterior diameter of alveolus, first incisor	8^{mm}
" second "	13
" canine	17
" pm_1	17
" p_2	18
" p_3	19
" p_4	18
Estimated depth from top of coronoid to angle of jaw	10^{cm}
Depth of jaw behind p_4	6·1
" " below p_3	6
" " " p_2	6·9
" " " p_1	7·5
" " " canine	5
Height of canine crown	21^{mm}
Extreme length of symphysis	11^{cm}
Thickness of ramus	3·5
Breadth of jaw opposite canine (estimated)	7

The species is named in honor of Dr. J. A. Allen of the American Museum of Natural History, author of well known contributions on the Pinnipedia and other marine Mammalia.

Relationships of Prorosmarus.

Prorosmarus seems to have been only one of a number of genera of Odobænidae which must have flourished during the late Miocene and Pliocene epochs. Of these, the European forms

Alachtherium cretsii DuBus (figs. 3, 4B) and "*Trichechodon*" *koninckii* Van Beneden from the lower Pliocene (Scaldisien, probably homotaxial with the Plaisancien of the Mediterranean region) near Anvers in Belgium, and *Trichechodon huxleyi* Lankester from the "red crag" of Suffolk, England, have been fully described and figured by Van Beneden in his

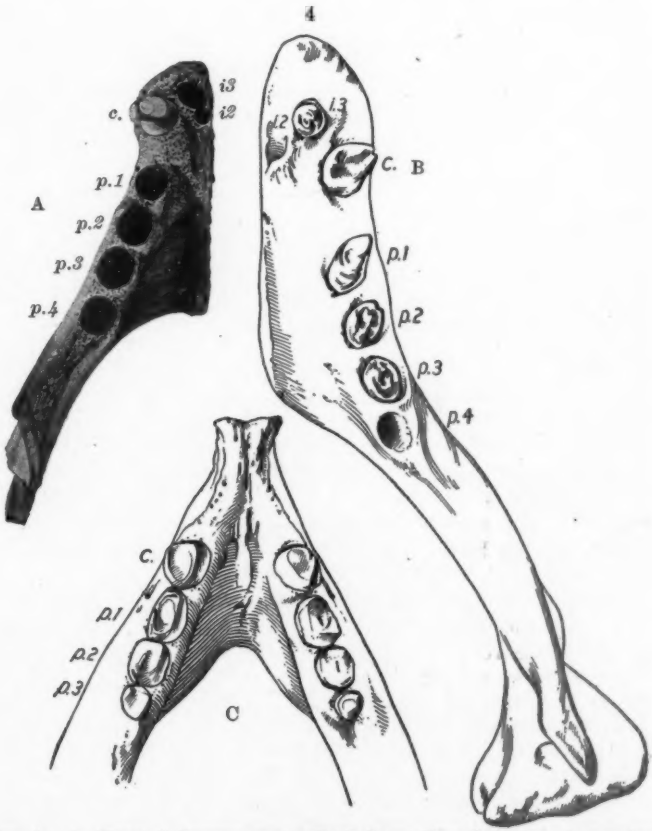


FIG. 4. A. Type of *Prorosmarus alleni*, lower jaw (left ramus) superior view. B. Type of *Alachtherium cretsii*, lower jaw (right ramus) superior view. (After Van Beneden.) C. Old male (cf. fig. 2) of *Odobœnus rosmarus* lower jaw, superior view. All one-third natural size.

Description des Ossements Fossiles des Environs d'Anvers (Ann. Mus. roy. d'His. nat. de Belgique, tome 1, 1877).

The mandible of *Alachtherium* (figs. 3, 4B), has been identified as positively Odobænid, while at the same time retaining certain characters of the Otaries. It resembles that of *Prorosmarus* in the dental formula, in the general form and arrangement of the teeth, in the persistent separation of the opposite rami of the jaw at the symphysis, in the long sloping chin and the slender coronoid. It differs from the mandible of *Prorosmarus* in being relatively longer, more slender, and shallower, and much more upwardly curved anteriorly, the long axis of the symphysial face being almost at right angles to a line drawn through the front border of the coronoid. This implies a shorter, more upturned facial region. The distance from the last molar to the condyle is relatively greater and the bony "lip" of the jaw is much more produced anteriorly and lacks the eversion of the anterior margin. There is no narrowing of the upper border of the jaw immediately behind the canine, the inferior mental protuberance is much less marked, the posterior dental foramen is farther forward, and the jaw as a whole is much larger than that of *Prorosmarus*, the total length being about 37^{cm} from the incisive border to the condyle as against an estimated length of 21·5^{cm} in *Proromarus*. The molar series in *Alachtherium* measures about 9·5^{cm} as against 8^{cm} in *Prorosmarus*, that of the latter being thus relatively longer. The molars are also considerably more widely spaced and thus relatively smaller in *Alachtherium*, especially p_4. In *Alachtherium* the lower canine seems to be in a fair way towards being taken over into the molariform series and the projection and narrowing of the bony "lip" beyond the canine may foreshadow the compressed rostrum of *Odobænus*.

Trichechodon huxleyi Lankester is known only from imperfect upper canine tusks which were very large but not equal to, and more recurved than, those of the existing *Odobænus*. These tusks are correlated by Van Beneden with the remains described by him as "*Trichechodon*" *koninckii*. The latter animal agrees with *Prorosmarus* in possessing four lower "molars," but, as represented in Van Beneden's plates, was extremely short-jawed, with very short mandibular symphysis, stout ramus and very large transversely expanded molars. In front of the molars was a still larger excavation or sinus which apparently opened externally and served to lodge the presumably immense upper canine.

All these forms strengthen the inference that the Walruses have been derived from some primitive member of the Otariidæ, probably during the middle Tertiary.

ART. XLI. — *A new form of "Container" for use in Museums of Economic Botany;* by GEORGE LINCOLN GOODALE.

IT has been found so difficult to procure prismatic glass bottles with perfectly even sides and faces, that an attempt was made in May last, in the Botanical Museum of Harvard University, to prepare a new kind of "container" with a flat front. A simple modification of the well-known *passe-partout* appeared most practicable. Many experiments were tried in order to meet the obvious objections, and at last, a form was devised which has appeared to answer every reasonable demand. At the request of many correspondents, the following details are given.

The materials are (1) lantern-slide glass of best quality and of standard size. (2) Strips of hard wood of different widths, ranging from one-sixteenth of an inch to one inch, but of perfectly uniform thickness, namely one-sixteenth of an inch for the widths below one-half and one-eighth inch for the widths above this. (3) Strong fish-glue in a liquid form. That which comes in Dennison's tubes has proved satisfactory. (4) A strong solution of potassium dichromate or a twenty per cent solution of formalin. (5) Hard paraffin. (6) Strong binding-strips well made with good glue.

From three strips of the wood neatly fastened between two thoroughly cleaned glass slides, one procures a container of the desired thickness. This is filled with the specimen of seeds or other objects and then is closed by placing the fourth strip in position. All four edges are next dipped for an instant in the solution of potassium dichromate or of formalin, in order to render the glue, after drying and exposure to the sun, wholly unaffected by moisture. If preferred, these solutions may be put on with a brush. When the filled container is completely dry, the edges are placed in a thin layer of melted hard paraffin and quickly removed. On cooling, the excess of paraffin is carefully scraped off, and the binding-strips are then applied. The prepared container is now ready for installation in any exhibition-case. Its contents are proof against invasion by moisture or any museum pests. In the very few instances where insects have been subsequently detected in the container, a small hole was made in one side of the wood, and a little carbon disulphide or chloroform thrown in by a medicine-dropper, and then the hole was closed by a bit of soft wax. In no case has it been found necessary to repeat the dose.

When the specimen is a powder which it is desired to show in a thin layer, it has been found well to proceed in a different manner. First, a flat cell is made by cementing with glue the thinnest strips of wood, on all four sides, and then drying the whole. Into this cell the powder can be put in a perfectly even layer, and then covered carefully by the other slide.

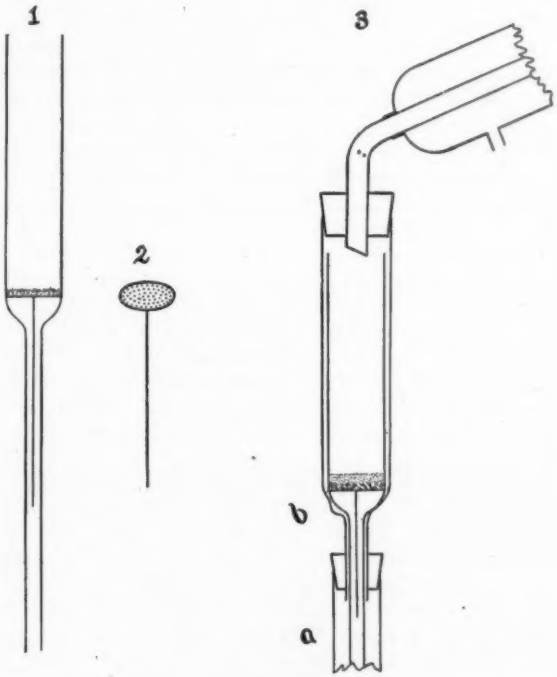
Among the advantages which this easy method possesses are the following,—economy of material, absence of distorting refractions of the container, a convenient tablet form for any exhibition-case, and a free space for labelling. To these advantages may be added the slighter but not unimportant ones; exposure of both sides of the specimen, and security against damage when used as a hand-specimen for class-work. When the container is filled and finished, the whole work and the materials used in construction have together cost less than unsatisfactory bottles.

Cambridge, May, 1906.

ART. XLII.—*Filter Tubes for Collection of Precipitates on Asbestos;* by S. L. PENFIELD and W. M. BRADLEY.

THE tubes described in this article may be employed to advantage in a variety of analytical operations, and as an inexpensive substitute for a Gooch crucible, where a high temperature is not required.

The tubes (figure 1) may readily be drawn out from combustion tubing, or made from soft glass if high temperatures



are not used. Different lengths and sizes will find a variety of uses, and diameters from 17 to 20^{mm} may be recommended for general use. The most satisfactory support for asbestos is a perforated platinum disc 0·2^{mm} in thickness, to the center of which a platinum wire three inches long is soldered (figure 2). Where conditions or expense prohibit the use of platinum, a fitter bed of quartz may be substituted with excellent results.

A large fragment is used to close the throat of the filter tube, and on this is placed a layer of powdered quartz about six or eight times as coarse as sea sand, from which fine material has been carefully removed by screening and washing. In order to deposit a uniform layer of asbestos on the quartz, it is recommended to observe the following precautions: The bottom of the filter tube is closed with the finger, and the tube is half filled with water; asbestos suspended in water is then added, when upon removing the finger, it will settle in a smooth layer upon the quartz, and may be firmly fixed by use of a filter pump. The asbestos and precipitate collected on it dry slowly in the tubes in an ordinary drying oven, but removal of water may be quickly accomplished by drawing a slow current of air through the tubes, the latter being heated in an air bath, which may be improvised from a baking powder can. Such filters may be found useful for collecting many precipitates which need not be subjected to strong ignition, silver chloride for example, and they are especially recommended for precipitates which are subsequently to be ignited in gases, as will be illustrated by numerous examples. They are admirably adapted for use with an extractor, where either a precipitate collected on the asbestos, or a powder, is to be treated with some solvent, such as either, carbon bisulphide or alcohol. The arrangement of a filter tube in an extractor is suggested by figure 3, where *a* is the neck of a flask containing some solvent, the vapors of which pass up between the filter tube and the outer jacket, and after condensation drop down upon the material collected on the asbestos. At *b* there should be some swelling of the tube to allow a free upward passage of vapors.

In case of a small amount of organic material being present, it could undoubtedly be burned in the tube in oxygen gas and the resulting carbon dioxide and water collected and weighed.

Precipitates collected on the asbestos can be ignited by applying a gentle heat to the tubes while supported in an inclined position, or the following arrangement may be found very serviceable: a small hole is pierced in the bottom of a porcelain crucible and enlarged by chipping until a hole of the desired diameter is obtained, through which is passed the smaller part of the filter tube. The crucible not only serves as a support for the tube, but also protects the glass and precipitate from too strong ignition. A ring burner is placed beneath the crucible, and so adjusted that the lower part of the filter tube passes through the center of the burner, and may by its lower end be connected to a gas generator. If it is desired to increase the temperature of the upper part of

the tube, this may be accomplished by using wire gauze, so placed as to deflect the heat to that portion.

In order to test the apparatus just described with precipitates requiring ignition in gases, a number of experiments have been carried out with the following results:

Calcium ignited in CO_2 and weighed as $CaCO_3$

	Precipitated as $CaCO_3$	Precipitated as CaC_2O_4
Calcite taken	0·7445	0·7191
$CaCO_3$ weighed	0·7450	0·7195
Error	0·0005 +	0·0004 +
Error as CaO	0·0003	0·0002

The collection of a considerable portion of calcium oxalate on an asbestos filter can scarcely be recommended because the exceedingly fine precipitate clogs the asbestos and makes the filtration tedious.

Copper in recrystallized copper sulphate was precipitated by means of hydrogen sulphide and ignited in CO_2.

$CuSO_4.5H_2O$ taken = 0·1936,	Cu_2S calculated	0·0617
	Cu_2S weighed	0·0618
	Error	0·0001 +

Zinc in recrystallized potassium double sulphate $K_2SO_4.ZnSO_4.6H_2O$ was precipitated by hydrogen sulphide in formic acid solution; ignited in CO_2, and, weighed as ZnS.

$K_2SO_4.ZnSO_4.6H_2O$ taken 0·5265,	ZnO calculated	0·0965
	ZnO determined	0·0960
	Error	0·0005 −

Lead in pure galena was precipitated by hydrogen sulphide in acetic acid solution, after decomposing the mineral with nitric acid, and dissolving lead sulphate with ammonium acetate. Lead sulphide was ignited in hydrogen sulphide and weighed.

Galena taken	0·2494
PbS weighed	0·2494
Error	0·0000

Arsenic in sublimed arsenious oxide was precipitated by hydrogen sulphide after dissolving in pure sodium carbonate, and acidifying with hydrochloric acid.

The arsenious sulphide was subjected to the action of carbon bisulphide for the removal of sulphur, using the extractor illustrated by figure 3.

As_2O_3 taken 0·1890,	As_2S_3 calculated	0·2350
	As_2S_3 weighed	0·2357
	Error	0·0007 +

Antimony in Japanese stibnite was precipitated by hydrogen sulphide after dissolving the mineral in hydrochloric acid. The Sb_2S_3 was ignited in CO_2 gas.

Stibnite taken	0·1385
Sb_2S_3 weighed	0·1384
Error	0·0001 —

Bismuth in pure Bi_2O_3 was precipitated by hydrogen sulphide after dissolving the oxide in the least possible amount of dilute nitric acid, and diluting largely before precipitation. Bi_2S_3 was ignited in CO_2 and weighed.

Bi_2O_3 taken	0·3047
Bi_2O_3 determined	0·3046
Error	0·0001 —

Thanks are here expressed to Dr. W. E. Ford, who kindly furnished the results of the last two determinations.

Filter tubes such as here described have been in use for many years in our laboratory, and have frequently been employed in the estimation of potassium as platinic chloride; on subsequent ignition in hydrogen gas the salt may be decomposed, the alkali chloride extracted with water, and tested spectroscopically for cæsium and rubidium.

Mineralogical Laboratory of the Sheffield Scientific School of Yale University, New Haven, Conn., March, 1906.

ART. XLIII.—*Age and Type Localities of the Supposed Jurassic Fossils collected North of Fort Bridger, Wyoming, by Frémont in 1843;** by A. C. VEATCH.

ON August 19, 1843, having turned north from Fort Bridger on the Oregon Emigrant Road and passed over Muddy Fork, or Big Muddy (which he refers to as "a salt creek about 15 feet wide") near the present site of Carter, Uinta County, Wyo., Frémont reports† that he crossed a high ridge "and descended upon one of the heads of Ham's Fork called Muddy, where we made our midday halt. In the river hills at this place I discovered strata of fossiliferous rock having an oolitic structure, which in connection with the neighboring strata authorizes us to believe that here on the west side of the Rocky Mountains we find repeated the modern formations of Great Britain and Europe which have hitherto been wanting to complete the system of North American geology. In the afternoon we continued our road, and searching among the hills a few miles up the stream and on the same bank I discovered among alternating beds of coal and clay, a stratum of white indurated clay containing very clear and beautiful impressions of vegetable remains."

These specimens were referred to James Hall, who described them‡ and gave the following additional details regarding the locality, evidently based largely on Frémont's notes.§

"Longitude 111°, latitude 41½°, Muddy River.—These specimens are of a yellowish gray oolitic limestone, containing turbo, cerithium, &c. The rock is a perfect oolite; and, both in color and texture, can scarcely be distinguished from specimens of the Bath Oolite. One of the specimens is quite crystalline, and the oolitic structure somewhat obscure. In this instance, the few fossils observed seem hardly sufficient to draw a decisive conclusion regarding the age of the formation; but, when taken in connection with the oolitic structure of the mass, its correspondence with the English oolites, and the modern aspect of the whole, there remains less doubt of the propriety of referring it to the Oolitic period. A further collection from this interesting locality would doubtless develop a series of fossils, which would forever settle the question of the relative age of the formation.

* Published with the permission of the Director of the Geological Survey.

† Frémont, Capt. J. C., Rept. of Exploring Expedition of the Rocky Mountains in the Year 1842, and of Oregon and Northern California in the years 1843–44, 28th Congress, 2d Session, House Executive Document No. 166, 1845, p. 131.

‡ Ibid., pp. 304–310. § Ibid., pp. 297–298.

"A few miles up this stream, Capt. Frémont has collected a beautiful series of specimens of fossil ferns. The rock is an indurated clay, wholly destitute of carbonate of lime, and would be termed a fire clay. These are probably, geologically as well as geographically, higher than the oolite specimens, as the rocks at this place were observed to dip in the direction of N. 65° W. at an angle of 20 degrees. This would show, conclusively, that the vegetable remains occupy a higher position than the oolite. Associated with these vegetable remains, were found several beds of coal differing in thickness. . . . . .

"The stratum containing the fossil ferns is about 20 feet thick; and above it are two beds of coal, each about 15 inches. These are succeeded by a bed of sandstone. Below the bed containing the ferns, there are three distinct beds of coal, each separated by about 5 feet of clay. Before examining the oolitic specimens just mentioned, I compared these fossil ferns with a large collection from the coal-measures of Pennsylvania and Ohio, and it was quite evident that this formation could not be of the same age. There are several specimens which I can only refer to the *Glossopteris Phillipsii*, an Oolitic fossil; and this alone, with the general character of the other species, and the absence of the large stems so common in the coal period, had led me to refer them to the Oolitic Period. I conceive, however, that we have scarcely sufficient evidence to justify this reference; and though among the fossil shells there are none decidedly typical of the oolite, yet neither are they so of any other formation; and the lithological character of the mass is not reliable evidence."

A portion of this material found its way into the National Museum and was examined by Lesquereux, who likewise considered it Oolitic.* No similar plant remains were found by any of the several Government expeditions which visited this region after the early exploration of Frémont, and while Dr. A. C. Peale, who studied the region just north in 1877, and was therefore familiar, in a general way with its stratigraphy, attempted in 1898 to determine, in the office, from Frémont's account the locality from which the fossils were obtained, no satisfactory conclusion was reached. Dr. Peale called my attention to this unique material and the desirability of determining the true stratigraphic position of the original locality, and of making additional collections.

A special search for this locality was therefore made in connection with my study of the coal and oil fields of this general region during the summer of 1905. From this study and a careful consideration of the original notes of Frémont

*Prof. U. S. National Museum, vol. xi, 1888, pp. 37–38.

and Hall, quoted above, the locality which furnished the leaves was determined to be on the south bank of Little Muddy Creek, about one mile east of the present town of Cumberland. A considerable collection of plants of the same type was obtained from just north of the creek, and studied by Dr. Knowlton, who reports as follows:

"Plants from Sec. 29, T. 19 N., R. 116 W. One mile E. of Cumberland.

Gleichenia. Two or three species, well preserved.
Equisetum? sp. Peculiar, probably new.
Aralia, cf. *A. Saportana.*
Dewalquea, near *D. insignis.*
Peculiar radiate plant of unknown affinity.

"This is extremely interesting material as it is evidently from the same locality or horizon as that at which Fremont obtained a small collection in 1842, which was worked up by James Hall, who referred the beds to the Jurassic. The ferns here called Gleichenia were named Pecopteris by Hall, but they seem indistinguishable from this modern genus. The age, so far as I am able to fix it, is the lower part of the Upper Cretaceous, about in the position of the Turonian, possibly a little lower."

This horizon is stratigraphically 1,200 feet below the thick sandstone, which here forms the very prominent topographic feature known as Oyster Ridge. The geological position of the plant-bearing beds, as determined by stratigraphic data and invertebrate fossils identified by Dr. T. W. Stanton, is clearly Benton or lower Colorado. The leaf-bearing beds are underlain by black shales containing abundant fish scales, which were observed by the early explorers near Aspen, and which they correctly referred to the Benton. These fish-scale beds are underlain by the fossiliferous Bear River formation. The coal-bearing series containing the fossil plants yield at many points invertebrates with distinct Benton characteristics, and about 3,000 feet above the Oyster Ridge standstone numerous specimens of the characteristic Niobrara form, *Inoceramus exogyroides*, were found.

The invertebrates described by Hall as *Cerithium nodulosum* and *Turbo paludinæformis** came from the bluffs 3 or 4 miles east of this locality, which here present a scarp face capped by this fossiliferous, somewhat oolitic limestone. These beds dip gently eastward, and it was clearly Hall's unwarranted assumption that both the plant-bearing beds and the oolitic limestone had the same dip that led to the conclusion that the fossils came from a lower horizon than the leaves.

*Ibid., p. 309, pl. iii, figs. 11, 12, 13.

The limestone is stratigraphically near the line of parting between the Wasatch and Green River formations. Both Meek* and White† have recognized the identity of these forms with those found in beds of undoubted Eocene age at about the same horizon, and have thus anticipated from paleontologic data the conclusion reached by visiting the type locality. Meek pointed out that the Cerithium is clearly a Goniobasis, and suggested the name of *Goniobasis nodulifera*, while White regards it as but a variety of *Goniobasis tenera* (*Cerithium tenerum* Hall). *Turbo paludinæformis* has likewise been referred to the fresh water genus, *Vivipara*.

Of Frémont's supposed Jurassic fossils, the plants are therefore upper Cretaceous and the invertebrates are Eocene.

U. S. Geol. Survey, Washington, D. C.

*Meek, F. B., 4th Ann. Prelim. Rept. U. S. Geol. Survey of the Territories for 1870, 1872, p. 299. Rept. Geol. Expl. 40th Parallel, vol. iii, 1877, pp. 179–180.

†White, Chas. A., 11th Ann. Rept. U. S. Geol. and Geog. Survey of the Territories for 1877, 1879, pp. 226–227.

Art. XLIV.—*Certain Suggestions by J. Willard Gibbs on Geophysical Research.*

Note.—Some years ago when I was interested in physical geology and after some progress had been made, I endeavored to secure the coöperation of Prof. J. W. Gibbs on the theoretical side, hoping to carry out the experimental part suggested myself. Prof. Gibbs entered into the project cordially and wrote out for me a plan of attack. Unfortunately, and to my lasting regret, circumstances beyond my control made it impossible for me to live up to my part of the project, and the scheme proved barren of results.

The suggestions of Gibbs are given below. They must be read with a time allowance for the intervening years and with the reservation that Gibbs, who was chary of print, would not probably have published them himself. On the other hand, I do not feel justified in withholding what Gibbs counseled on a subject in which he was so admirably qualified to judge, from those who may be interested in geophysical research. Carl Barus.

A good deal of work has been spent in the endeavor to find equations which shall represent the relations p, t, v, for various substances. It would be very pleasant to have such an equation, but it is doubtful whether the relation *can* be represented by any simple formula.

Now instead of comparing the relation in any given case with an analytical formula, one may compare the relations for different substances with each other. Van der Waals has given an algebraic equation which would make the law *similar* for all substances, in this sense, that by measuring the t, p, v, for different substances in different units, the numerical expression of the relation becomes identical for all substances. Now Van der Waals' law gives only a very rough approximation. But it is worthy, I think, of much effort to find out whether, or with what degree of approximation, and within what limits, and with what exceptions, the actual laws for different substances are *similar* in the sense defined above. And if not similar, to find how many degrees of variation there are, in addition to the three connected with the measure of temperature, pressure and volume. In other words, to find how many independent constants there are in the general formula, i. e., in a formula sufficiently general to be so called. Certain cases would probably remain, which would naturally be regarded as exceptional or "abnormal."

The method to be followed would appear in the course of the investigation, but we might commence as follows. Suppose we find for various substances the limiting values of

$d \log p/d \log t$ for saturated vapor at the critical state. The units of temperature and pressure fall out of this expression. If Van der Waals' Law were exact, the value of this expression for all substances would be 4. Actual values seem to be much higher than this. Suppose we had a table of these values for a considerable number of substances. Will these values or a large part of them be identical? In any case we can probably find several substances which have nearly the same values. We may then ask whether, or how far, these substances, which have the same limiting values $d \log p/d \log t$, have *similar* relations between p, t, and v. This would perhaps be most easily tested by finding whether p/p_c is the same function of t/t_c for the saturated vapor of the several substances (t_c and p_c denote t and p for the critical state); and this again would be sufficiently and most easily tested by a few particular cases (for each substance), as $t/t_c = 9/10$ or $8/10$, etc.

In this way we might decide whether the general (or quasi-general) equation has three independent constants (which is all that Van der Waals' theory of "corresponding states" allows) or four or more than four. Uncritically we might push the inquiry further, if there are more than four, but with rapidly increasing difficulties of various kinds, and with diminishing value of the results obtained, since the most simple results are the most valuable.

Incidentally, such an investigation would enable us to distinguish those substances which are *typical* from those which are exceptional or "abnormal."

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Molecular Weight of Silver Vapor.*—Several years ago some vapor density determinations were made by Nernst at temperatures in the neighborhood of 2000° C. by the use of an iridium bulb in an electrically heated tube of iridium. The principle applied was that of Victor Meyer's method, but the process was ingeniously modified, on account of the rarity of iridium, by the use of a very small bulb, a specially devised micro-balance, and the measurement of the displaced air by means of the movement of a drop of mercury in a small, horizontal, graduated, glass tube. Nernst obtained interesting and satisfactory results with very minute quantities of several substances, but upon attempting to get the vapor density of silver his private assistant weighed a piece of platinum wire in place of supposed silver wire, so that the apparent result that silver was not volatile at 2000° was obtained. Wartenberg, using Nernst's apparatus and method, with the iridium bulb glazed inside with rare-earth oxides, so that the silver vapor would not attack the iridium, has now made some determinations with silver. The best results showed a molecular weight not far from 107, so that it appears that silver forms a monatomic vapor in the neighborhood of its boiling-point. From experiments made by Nernst it was found that the boiling-point of the metal was about 2050°, and the experiments under consideration were probably made at temperatures but little above this point.—*Berichte*, xxxix, 381. H. L. W.

2. *Carbon Oxybromide.*—Although phosgene, $COCl_2$, is well known and readily prepared, no method has been known, up to the present time, for preparing the corresponding bromide in a pure condition and in large quantity. A. von Bartel has studied this problem, and has found that while the oxybromide is formed by the direct union of carbon monoxide and bromine in the presence of aluminium bromide and also by means of the invisible electric discharge, a more satisfactory method of preparing the substance in quantity was found in the action of concentrated sulphuric acid upon carbon tetrabromide. The reactions that take place are as follows:

$$CBr_4 + H_2SO_4 = COBr_2 + 2HBr + SO_3;$$

then a part of the hydrobromic acid reacts with sulphuric acid:

$$2HBr + SO_3 = SO_2 + H_2O + Br_2.$$

To carry out the reaction, the sulphuric acid is allowed to drop slowly into the melted carbon tetrabromide at a temperature of about 150–160°. A strongly fuming, red distillate is produced, from which most of the free bromide is removed by the addition

of mercury at the temperature of ice-water. The liquid is then distilled and freed from the remaining bromine by means of powdered antimony. In the pure condition the oxybromide is a fuming, colorless, mobile liquid boiling at 64–65°. It is unstable, decomposing somewhat upon distillation, and being almost completely decomposed when its vapor is subjected to a red heat. It acts but slowly upon water at ordinary temperature. Its specific gravity is 2·45 at 15°.—*Liebig's Ann.*, cccxlv, 334. H. L. W.

3. *The Industrial Preparation of Calcium Hydride.*—It was shown by Moissan that metallic calcium absorbs hydrogen when heated, forming the colorless hydride CH_2, and it is interesting to learn from an article by JAUBERT that this substance has already been made on a commercial scale for the purpose of preparing hydrogen for balloons. It is well adapted for this purpose since it reacts with water according to the equation

$$CaH_2 + 2H_2O = Ca(OH)_2 + 2H_2.$$

One kilogram of the substance thus liberates a cubic meter of pure hydrogen. Metallic calcium is manufactured by the electrolysis of the fused chloride. The electrical energy required for producing 100 kilograms of the metal in 24 hours is about 20 volts and 7,500 amperes, or 150 kilowatts. The hydride is prepared by heating the metal to a high temperature in horizontal retorts in which hydrogen circulates. The gas is slowly absorbed, and after several hours all the calcium is transformed into the hydride. The commercial product occurs in white or gray, irregular porous pieces, having considerable hardness. It is insoluble in the common organic solvents, but is instantly decomposed by cold water, similarly to calcium carbide. The product is about 90 per cent pure, the impurities being chiefly oxide and nitride.—*Comptes Rendus*, cxlii, 788. H. L. W.

4. *The Synthesis of Cyanogen and of Hydrocyanic acid from the Elements.*—It is stated in most of the chemical text-books and reference-books that cyanogen gas has been produced (by Morren) by the passage of the induction spark between carbon points in an atmosphere of nitrogen. THEODORE WALLIS shows that the electric arc, instead of the induction spark, was probably used in the original experiments, and he shows further that by neither of these means is cyanogen produced. The error has arisen from the fact that hydrocyanic acid gas is formed in the presence of moisture under the conditions of the experiment, and the mistaking of this gas for cyanogen. The author has made a careful study of the methods of distinguishing and determining HCN and $(CN)_2$ in the presence of each other. The most satisfactory means of separating them appears to be based upon the fact that neutral or acid silver nitrate solution does not absorb $(CN)_2$, while it does absorb HCN.—*Liebig's Ann.*, cccxlv, 353. H. L. W.

5. *A Gaseous Hydride of Calcium in Acetylene.*—HOFFMEISTER has noticed that acetylene when prepared from certain specimens

of calcium carbide, even after having been filtered through cotton and passed through water, deposited lime in the conducting pipes. This fact seemed to indicate the presence of a volatile compound of calcium in the gas. In order to study the matter further, a large volume of the acetylene was passed through a number of wash-bottles containing acetone, then through ammoniacal copper solution to remove the acetylene completely. A colorless gas was thus obtained, which burned in the air to calcium oxide and water, and formed an exceedingly explosive mixture with oxygen, As the gas was not obtained quite free from air, its quantitative composition has not yet been determined.—*Zeitschr. anorgan. Chem.*, xlviii, 137. H. L. W.

6. *The Electrical Nature of Matter and Radioactivity;* by HARRY C. JONES. 8vo, pp. 212. New York, 1906 (D. Van Nostrand Company).—In this book Professor Jones gives a very clear and interesting account of the recent developments in regard to gaseous ionization, electrons, rays of various kinds and radio-active bodies. The style is semi-popular and non-mathematical, so that it is well adapted for the use of the general scientific reader. The work is to be highly recommended to those who desire to obtain an insight into the fascinating fields of work in which J. J. Thomson, Becquerel, the Curies, Rutherford and many others have been laboring. H. L. W.

7. *Energy, Duration, Damping and Resistance of Condenser Sparks.*—The art of wireless telegraphy has given a new importance to the study of electric sparks. A. HEYDWEILLER contributes an interesting paper upon the necessity of adding another term to Lord Kelvin's celebrated differential equation which expresses energy relations in regard to the discharges of a condenser. This new term expresses the spark energy: the resulting differential equation is complicated and its integration in the words of the author "must remain a pious wish"; still several solutions can be obtained by making suitable suppositions in regard to the electrical constants of the circuit. Heydweiller finds that the resistance of the condenser sparks which are usually employed in wireless telegraphy is less than an ohm.—*Ann. der Physik*, No. 4, 1906, pp. 649–691. J. T.

8. *Magnetic Relations of Powdered Iron of Various Densities.*—W. TRENKLE finds that, with equal magnetizing forces, the magnetization and susceptibility of clean iron powder is always greater than a mixture of iron powder and a non-magnetic substance: the magnetization of the iron sinks cet. par. with its density.—*Ann. der Physik*, No. 4, 1906, pp. 692–714. J. T.

9. *Spectrum of the High Tension Flaming Discharge.*—This discharge results from the high degree of ionization which is produced from the terminals of a transformer which is excited by a powerful current in the primary of the transformer. It is also the characteristic discharge of a high tension storage battery. B. WALTER finds that the spectrum of this discharge contains some very characteristic bands in the ultra-violet end of the spec-

trum which are the same bands that J. M. Eder discovered by burning a mixture of ammonia gas and hydrogen in oxygen. Walter believes that the discovery of these bands will be of use in the commercial attempt to oxidize nitrogen by the electric spark.—*Ann. der Physik*, No. 4, 1906, pp. 874–876. J. T.

10. *Photography of a Radium Crystal by its Own Light.*—B. WALTER has succeeded in photographing a particle of radium by its own light; and finds that there is considerable variation of light in different portions of the particle. One portion of the crystal which exhibited very strong light when examined under the microscope showed a rupture of its surface. It seems possible that craters are formed which are centers of atomic convulsions.—*Ann. der Physik*, No. 5, 1906, pp. 1030–1031. J. T.

11. *Ions, Électrons, Corpuscules. Mémoires réunis et publiés* par H. ABRAHAM et P. LANGEVIN. 2 vols., xvi + 1138 pp. Paris, 1905 (Gauthier-Villars).—These volumes, issued by the French Physical Society, contain a collection of papers and extracts from papers, bearing upon the modern theory of the atomic constitution of electricity. This theory forms the basis of most of the work which has made the last decade a memorable one in the history of physics; it has come to occupy a position of such fundamental importance in many different branches of the science, that the student who is not fairly familiar with its details is at a decided disadvantage. The development of the theory has been rapid, it has been applied to a great variety of problems, and important papers are widely scattered among the scientific periodicals of the world. It thus becomes a matter of some difficulty to gain an adequate knowledge of the present point of view, unless one has been particularly interested in the subject from the first.

The present volumes will give most useful help in this difficulty, and will prove a great convenience even to those who are familiar with the subject. The selection of papers for reprinting has been made with great care and with admirable judgment. The arrangement is alphabetical with respect to authors, but a well-classified topical index makes it possible to read the papers upon any portion of the subject in a continuous manner. In addition to numerous subdivisions dealing with the different modes of production of electrons and gaseous ions, and the experimental study of their properties, there is also a series of papers upon the dynamics of electrons, with applications to optics, to the phenomena of radiation and metallic conduction. Extensive and important theories, such as those of Lorentz and Larmor, are summarized by the authors themselves with numerous extracts from published papers.

It would be exceedingly difficult, if not impossible, for any one to write a treatise which would give the reader so broad and so just a view of the state of our knowledge of ions and electrons as do the present volumes. A feeling of reality and intimacy comes from reading the original papers in which important discoveries were announced to the world, which is seldom gained from a

second-hand account. There is also the advantage of seeing with the eyes of many men and not being dependent upon the particular point of view of a single author. A careful examination of this book can scarcely fail to convince the reader that the editors have selected the best possible method of presenting the subject; they have carried out the method with a degree of judgment and discrimination which deserves hearty admiration. H. A. B.

12. *Laboratory Course in Physical Measurements;* by W. C. SABINE, A.M. Pp. vi+97 (Ginn & Co).—This is a revised edition of a laboratory manual by Professor Sabine, first published in 1893. Brief directions are given for making about thirty simple physical measurements, suitable for a class of students who have had no mathematics beyond trigonometry. The experiments are well chosen, and the directions are especially to be commended in that they leave many details to be thought out by the student for himself—a process of great educational value, which is often absent from laboratory instruction. H. A. B.

II. GEOLOGY AND NATURAL HISTORY.

1. *Contributions to the History of American Geology;* by GEORGE P. MERRILL. Rept. U. S. Nat. Mus. for 1904, pp. 189–733, 37 plates, and 141 text-figures, 1906.—During odd moments, the Head Curator of the Department of Geology in the U. S. National Museum has collected the material for this history of the growth of geology in North America. Far more information was secured than appears in the printed work. The mode of presentation, the author states, aims to "show not merely what has been done, by whom, and how it has been done, but the gradual growth of the science and the development of powers of observation and deduction as well. To do this satisfactorily, no other arrangement than a chronological one seemed possible."

The book is divided into eleven chapters under the following headings: The Maclurean Era, 1785–1819 (Chapter I), The Eatonian Era, 1820–29 (II), The Era of State Surveys, 1830–1879, (III–VII), The Fossil Footprints of the Connecticut Valley (VIII), The Eozoon Question (IX), The Laramie Question (X), and The Taconic Question (XI).

Up to 1802, "none of the sciences were taught in the colleges and other institutions of learning in America." In 1798, Professor Dwight began to move for the "establishment in Yale College of a department for the teaching of these subjects," and in 1802 Benjamin Silliman was appointed professor of chemistry and natural science in that institution. Silliman was then twenty-two years of age, a tutor in law, "without even the most rudimentary knowledge of the science he was to teach." He then repaired to Philadelphia and for five months attended the lectures on chemistry given by Dr. James Woodhouse in the Medical School of Philadelphia. His own first lecture at Yale

was delivered April 4, 1804. In 1805 he went abroad to fit himself more fully for the duties of his professorship. Silliman "through his own efforts as a teacher, but more particularly through his personal influence as a writer and lecturer, probably" did "more to advance the science of geology than any man of his day."

From Silliman as the first teacher of geology in America, the history rapidly passes to Maclure, "the father of American geology." He produced the first geological map of the United States in 1809. Only three other geological maps had been thus far published. The next prominent figure is Parker Cleaveland, appointed in 1805 to the professorship of mathematics, natural philosophy, chemistry, and mineralogy in Bowdoin College, and the author of "Elementary Treatise on Mineralogy and Geology," 1816. It "was the first attempt made in America at a systematic treatise on Mineralogy."

In 1818 the American Journal of Science was founded by Benjamin Silliman, "and a perusal of the numbers from the date of issue down to the present time will, alone, afford a fair idea of the gradual progress of American geology." In this same year appeared S. L. Mitchill's "Observations on the Geology of North America," Amos Eaton's "Index," and Edward Hitchcock's first geological paper. These various publications make the year 1818 stand out prominently as one of the great milestones in American geology.

The first Geological Society of America was organized in 1819, in the philosophical room of Yale College, with Maclure as president. In looking over the more prominent members of this society, one is struck by the many names now among the fathers of American geology; as Gibbs, Silliman, Cleaveland, Akerly, Bruce, S. L. and J. F. Dana, Dewey, Eaton, Hitchcock, Mitchill, Rafinesque, Schoolcraft, Emmons, Harlan, Lea, Morton, Troost, and Vanuxem.

Among the admirable features of this book, in addition to the many portraits, are the maps giving the routes of travel of the various expeditions into the then unknown country; as Schoolcraft, 1820, 1821, Long, 1819–20, 1823, Stansbury, 1849–50, Foster and Whitney, 1847–49, Marcy and Shumard, 1849–52, Pacific R. R. Surveys, 1853–56, Ives and Newberry, 1857–59, Raynolds, 1859–60, etc.

This work, much of which is written in a vein of dry humor, is so full of interest and its presentation is so admirable that no geologist can afford to be without it. Its preparation has been a labor of love, and has been mainly accomplished out of official hours during the past several years. It is a worthy companion volume to Geikie's "The Wonders of Geology." C. S.

2. *Revision of Paleozoic Insects;* by ANTON HANDLIRSCH. Proc. U. S. Nat. Mus., xxix, 1906, pp. 661–820.—This work is not only a complete study of the entire collection of American Carboniferous and Permian insects (about 750 specimens) in the

U. S. National Museum, but also includes a revision of all previously described species. The author recognizes 345 species (137 renamed or new) distributed in 169 genera (109 new). All this material is properly located in the geological formations by Mr. David White, on pages 664–668, and the horizons are correlated with standard European sections.

The horizontal distribution leads Handlirsch to the following conclusions: "Nearly all the orders occurring in America have likewise been already recognized in analogous European beds; in like manner almost all the families rich in forms have been identified in both parts of the world. In such groups as first exist in single individuals, no sort of conclusion as to their actual horizontal distribution can obviously be drawn, and it consequently follows that there is a striking agreement in the Paleozoic fauna in both continents. Only one order (Blattoidea) represented in the Paleozoic of America extends over into the Mesozoic, with two families, while all other orders are replaced in the younger formations by those more highly specialized.

"Moreover, from a percentile comparison of the number of forms represented in the single orders in the various formations of the Paleozoic, it follows that the Palaeodictyoptera, which on morphological grounds I consider the stem group of all winged insects, appear first and decrease from the oldest beds to the younger, while the more highly specialized orders (Prodonata, Megasecoptera, Hadentomoidea, Hapalopteroidea, Mixotermitoidea, Protorthoptera, and Protoblattoidea), which I regard as connecting links between the Palaeodictyoptera and modern insect groups, and which may be designated *transitional* groups, appear later than their conjectural ancestors, attain their maximum in the middle beds, and with the close of the Paleozoic again vanish. It follows finally that the single modern order, thus far found in the American Paleozoic, the Blattoidea, first makes its appearance toward the middle of this period and continues with progressive increase to the close." C. S.

3. *A Study of the James Types of Ordovician and Silurian Bryozoa;* by RAY S. BASSLER. Proc. U. S. Nat. Mus., xxx, 1906, pp. 1–66, pls. 1–7.—Many of the Bryozoa described by the Jameses, father and son, have long remained in an obscure condition. The types now in the Walker Museum of the University of Chicago have been restudied by Bassler and adjusted to modern requirements. Of the 77 species described by James and James 44 are recognized, 32 are rejected, and 1 is a sponge.

C. S.

4. *Notes and Descriptions of Upper Carboniferous Genera and Species [of Ostracoda];* by E. O. ULRICH and R. S. BASSLER. Proc. U. S. Nat. Mus., xxx, 1906, pp. 149–164, pl. 11.—The new genus *Paraparchites* (1 species) is described; also new and old forms of the following genera: *Beyrichia*? (2), *Beyrichiella* (3), *Kirkbya* (2), *Cythere*? (1), *Bairdia* (2), *Cypridina* (1).

5. *The Osteology of Protostega;* by G. R. WIELAND. Mem. Carnegie Mus., Pittsburg, Pa., ii, 1906, pp. 279–298, text-figs., and

pls. 31–33.—This excellent paper describes and illustrates in detail the large marine turtle *Protostega gigas*, of which two good specimens have recently been secured by Mr. Sternberg for the Pittsburg Museum. Cope estimated the entire length of this turtle to be 13 feet, but a restudy of the original specimen combined with this new material has shrunk the animal to a length of less than 6 feet. However, Wieland has elsewhere described a Cretaceous turtle from Dakota, *Archelon*, having a length of 13 feet. C. S.

6. *The Osteology of Diplodocus Marsh;* by W. J. HOLLAND. Mem. Carnegie Mus., Pittsburg, Pa., ii, 1906, pp. 225–264, pls. 23–30.—This paper treats of the additional material of the *Diplodocus carnegiei* collected since Hatcher's account published in the first volume of the same memoirs, and of the restoration of this animal recently presented by Dr. Carnegie to the British Museum of Natural History. Dr. Holland describes and figures in detail the fine skull secured by Mr. Utterback in 1902, and a fourth fine skull in the American Museum of Natural History. The author does not at all believe in the presence of a pineal eye at maturity in *Diplodocus*. Other parts described in detail are: The atlas, sternal plates, and supposed clavicle. Brief remarks are also made on the dorsal, sacral, and caudal vertebræ, and the chevrons. C. S.

7. *A New Ruminant from the Pleistocene of New Mexico;* by J. W. GIDLEY. Proc. U. S. Nat. Mus., xxx, 1906, pp. 165–167.—Describes an incomplete skull of a new bovine genus *Liops* from Juni, New Mexico.

8. *Report on the Lead and Zinc Deposits of Wisconsin with an Atlas of detailed maps;* by ULYSSES SHERMAN GRANT. Wisconsin Geological and Natural History Survey. Bulletin No. XIV. 100 pp., 26 pls., 10 figures in text.—This is a brief report on the geology of that portion of the Upper Mississippi Valley lead and zinc district that lies in the southwestern corner of Wisconsin. This area is one that is covered entirely by early Palaeozoic sedimentary deposits, there being no igneous or metamorphic rocks exposed although such rocks have been proven by means of deep borings to exist beneath the sedimentary series. The oldest sedimentary rock is the Potsdam sandstone, of Cambrian age. Upon this lies a dolomite, called the Lower Magnesian, which in turn is overlain by the St. Peter sandstone. Then come the two limestones, the Platteville (or Trenton) and the Galena formations in which lie the bulk of the productive ore deposits. These are covered with a shale series called the Maquoketo. All of these rocks belong to the Ordovician. In isolated places remnants of an upper Silurian limestone, the Niagara, are found.

Throughout the district as a whole the rocks have a low southwest inclination. In addition to this general monoclinal structure the district is covered by a series of gentle rolls of the strata, whose axes run approximately east and west. Most of the formations show a pronounced series of joints. These are especially well

developed in the massive beds of the Galena dolomite and they play an important role in the deposition of the ores.

The ore minerals are chiefly galena, sphalerite and smithsonite, with which are associated marcasite and calcite. The ore deposits may be grouped into two divisions according to their form: first, those which occur in crevices, especially in the joints in the rocks and which are in the nature of vein deposits; second, those which are disseminated in small particles through certain beds of the rock and which are in the nature of replacement deposits. The ores have undergone the usual alteration through the agency of descending surface waters and present three distinct mineral zones. At the top there is a zone containing large masses of galena. Below this is a zone in which smithsonite is the important ore. This last zone ends at about the level of ground water and is succeeded below by a zone in which sphalerite is the dominant mineral. The ore materials were derived from the sedimentary rocks themselves, in which they existed in a disseminated condition as original constituents, by the action of underground waters, which dissolved them out from the mass of the rock and later redeposited them in their present positions. The ore deposits, at least in the majority of cases, were found to lie in the synclinal folds of the rocks.

The atlas accompanying the report contains 18 topographic and geological maps of the area. They are drawn on a large scale and the formations are mapped on them in detail. W. E. F.

9. *The Diamond Pipes and Fissures of South Africa;* by H. S. Harger. Trans. Geol. Soc. South Africa, vol. viii, 1905, pp. 110–134.—The author shows that in addition to the well-known volcanic necks which have been exploited for diamonds, great numbers of others exist in Central South Africa. They are found penetrating the beds of the Karroo System. Some are filled with basaltic rock and gave rise to overflows of lava, while others are filled with fragmental material, contain the kimberlite in which the diamonds occur and appear as the result of explosive action. The location and characters of a number of these are given, their minerals described and their origin discussed.

The following analyses of the altered kimberlite, called "blue ground" when soft, and "hardibank" when hard, from the Vogelfontein Mine are of interest:

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O
I	38·08	2·46	24·48	2·59	12·88	4·14	1·12	0·84
II	33·42	0·94	23·84	3·52	10·80	9·84	0·97	0·86
III	36·57	5·09	13·75	4·68	11·85	8·49	2·55	0·64

	Ign.	$H_2O^{100°}$	CO_2	P_2O_5	Cr_2O_3	MnO	TiO_2	S	Total
I	10·14	0·25	1·67	0·67	tr.	tr.	tr.	tr. =	99·32
II	7·83	0·43	5·88	0·89	tr.	0·0	0·0	tr. =	99·22
III	6·31	5·47	4·61	0·58	tr.	0·0	0·0	tr. =	100·59

I Hard, dark hardibank.
II Soft, light hardibank.
III Soft, blue ground.

Regarding the origin of the diamonds in these volcanic necks, the author is not inclined to agree with those who place great stress on the presence of enormous temperatures and pressures as necessary conditions, basing their views on the artificial formation of the mineral in contracting cast iron by Moissan and others. He adverts to Friedlander's experiments by which diamonds were formed by stirring molten olivine with graphite rods, and also to the fact that diamonds have been found in the mines in olivine and in garnet, both of which are original minerals in the kimberlite. From this he concludes that if the deep-seated ferromagnesian magma contained carbon or carbon-bearing gases, its crystallization into the minerals mentioned above would naturally give rise to the formation of diamonds. L. V. P.

10. *Petrogenesis;* by C. DOELTER. Pp. 256, 8vo. Braunschweig, 1906 (Vieweg & Sohn).—The author, who is well known, not only through his researches during the past in different fields of petrographic study, but latterly, especially by his experiments and those of his students in the artificial production of rocks and minerals, gives in this volume a general introduction to the formation of rocks, not only igneous rocks but crystalline schists and sediments as well.

The subject is treated both from the point of view obtained by geological observation and petrographic study, and also from the results recently gained by researches along the lines of physical chemistry. The work of different authorities and the views expressed by them upon a great variety of subjects, such as the differentiation of igneous rocks, are competently treated and often subjected to a temperate criticism which the author's learning and experience render just and valuable. As an introduction into the field of theoretic petrology the work will be of great service to geologists, mineralogists and chemists. It includes separate chapters upon the earth's interior and volcanic processes; upon the mode of occurrence of the igneous rocks in which the influences of pressure, of viscosity, of the rôle of mineralizing vapors, etc., are treated; upon the structure of igneous rocks; upon the differentiation of igneous magmas; upon the order of succession of magmas, etc., etc.

It is clear that a work of this character which contains so many theoretical views, often the personal ones of the author, invites much discussion and criticism and in this way will be a benefit to the science of petrology. Such discussion here would transcend the proper limits of this notice, but we think, for example, that the criticism of Professor Doelter of analytical methods used in rock analysis (p. 65) is given a somewhat sharper form than it justly deserves, and would tend, with those unfamiliar with such processes, to give a wrong impression. The methods of analysis to-day, which in the case of minerals such as tourmalines and hornblendes yield ratios of exceeding sharpness, naturally will give equal results in the case of rocks, which are only mixtures of the same oxides in somewhat different proportions, provided the

analyst has the proper skill and experience with which to use them. The weight of criticism should be laid rather on the analysts than the methods. L. V. P.

11. *Höhlenkunde;* von W. von Knebel. Pp. 222, with plates and figures, 8vo. Braunschweig, 1906 (Vieweg & Sohn).—The author in this volume has brought together all of the various facts, phenomena, and theories which concern the origin and occurrence of caves and also of "karst" formation. The classification of caves, the different kinds of rocks in which they occur; the influence of ground waters, as well as the subterranean springs and rivers with the life which they contain; the deposits found in them, the meteorological phenomena they exhibit; the influence they have exerted on the development of civilization, are illustrations of the variety of topics treated in this work.

The subject matter has been handled in a broad and yet comprehensive manner, and the text is embellished by a considerable number of excellent illustrations, which add to its value. Although written in a somewhat popular style, which thus makes the work suitable for a wide circle of readers, it will, nevertheless, be found a useful adjunct to the library of the working geologist and of the teacher. L. V. P.

12. *Coal Resources of Wyoming.*—A preliminary report on this subject by L. W. Trumbull is given in Bulletin No. 7 of the School of Mines, Univ. of Wyoming, Laramie. The total production of coal from the state for the year ending Sept. 30, 1905 was about five and one-half million tons.

13. *Over de Betrekking van het Bekken der Anthropoiden tot dat van den Mensch;* door Jan van der Hoeven Leonhard. 103 pages, 1 plate and 1 table. Amsterdam, 1905 (C. L. Petersen).—That a change in the habitual posture would affect the statical relations existing between one part of the skeleton and another, might be assumed as a matter of course. It is also well known that *luxatio coxæ*, for example, can bring about certain modifications of the bone, independent of disease. It may therefore be asked what would happen if the pelvis, for any cause whatsoever, should change its static relations to other parts of the skeleton; and these changed relations should take place with a change of posture?

The author has taken pelvic measurements on all anthropoid skeletons in Holland. In order to arrive at a more exact comparison with the human pelvis, he multiplied the measures of each pelvis by the quotient arising from dividing the length of the anthropoid vertebral column in question by the average length of the human pelvis. Through this reduction the natural relation of all the parts to each other is said to be retained.

Supposing that the ancestors of man resembled the anthropoids, the ancestral type of pelvis would have to undergo certain transformations in its transition to the present type, owing to the fact that the weight of the body and the counter-pressure of the

femur would operate in an entirely different direction than before. This assumption is supported in a convincing manner by the tabulated measurements. The latter tend to prove that the human pelvis, in its essential lines, can be derived from the anthropoid pelvis through the effect of static influences brought into action by a change of posture. They also throw light on the relation which exists between the pelvis of the infant and that of the adult. The difference between these two is known to rest almost exclusively on the operation of the above-mentioned forces, whose influence is manifested as soon as the erect posture is assumed. The measurements employed show in a striking manner that the infant pelvis occupies a position exactly between that of the adult and that of the anthropoid. The conclusion, therefore, is that the human pelvis must have developed from one closely related to that of the modern anthropoid.

G. G. MACCURDY.

14. *Catalogue of the Fossil Plants of the Glossopteris Flora in the Department of Geology, British Museum (Natural History). Being a Monograph of the Permo-Carboniferous Flora of India and the Southern Hemisphere;* by E. A. NEWELL ARBER. Pp. lxxiv, 255, with 51 figures and 8 plates. London, 1905.—Twenty years since, the catalogue of the Paleozoic Plants in the British Museum by Mr. Kidston was published. It has now been decided to prepare a series of detailed catalogues, and the first of these is the volume which is before us. It deals with the Glossopteris Flora, which, aside from its very great general scientific interest, is of much practical value to prospectors for coal in India and the Southern Hemisphere. This flora has not hitherto been comprehensively treated. The author gives an account of the less abundant and less known species as well as the characteristic types represented in the Museum collection, and also gives a revision of the older records from the standpoint of present knowledge.

15. *Catalogue of the Madreporian Corals in the British Museum (Natural History).* Volume V. *The Family Poritidæ.* II. *The Genus Porites,* Part I. *Porites of the Indo-Pacific Region;* by HENRY M. BERNARD, M.A. Pp. 303, with 35 plates. London, 1905.—This fifth volume of the catalogue of Madrepore corals is devoted to the genus Porites as represented in the Indo-Pacific region. This genus is more generally distributed in the warm seas than any other of the stony corals, and on account of its closeness of texture has played an important part in reef-building. The peculiar intricacy of the structure of the skeleton has hitherto been a difficult problem to the student of coral morphology; but the author remarks that, as the result of his labors, "the intricate skeleton of this genus can now be reduced to order and the principles of structure minutely described, although we are still far from having unravelled the exact nature of many of the variations." The difficulty of the problem will be realized from the further statement "that there

were, indeed, moments near the beginning of it when the writer was in despair and on the verge of resigning his undertaking altogether."

16. *The British Freshwater Rhizopoda and Heliozoa;* by JAMES CASH, assisted by JOHN HOPKINSON. Vol. I, Rhizopoda, part I, pp. 148, with 16 plates and 32 text-figures. London, 1905 (The Ray Society).—A systematic treatise designed to describe and illustrate as fully as possible all the species of rhizopods and heliozoans known to occur in Great Britain. The present volume takes up 14 genera of the order Amoebina and 3 genera of the order Conchulina, a new term proposed for the shelled freshwater rhizopods. Not all of the genera are tenable; for example, *Ouramoeba* was established by Leidy upon specimens of the common *Amoeba proteus*, on the body of which occurred a growth of a parasitic fungus, and the author follows Leidy's error in describing these fungi as protoplasmic filaments of the body of the rhizopod. The synonymy of the species is very complete. The illustrations are excellent, particularly those of the nine colored plates, and are mainly from drawings by the author. W. R. C.

17. *Guide to the Invertebrates in the Collection of the Boston Society of Natural History.*—The reference to the author of this work, on p. 336 of the April number, should have read Mrs. Sheldon instead of Mr. Sheldon.

18. *Notes from the Harvard Botanical Station in Cuba.*—The production of sugar-cane seedlings, to which reference has been made several times in this Journal, is now progressing very favorably. The wide geographical range of parents has enabled us to make interesting experiments in regard to the adaptive characters of the varieties. Our stock of varieties has been obtained at different times from Australia, Java, Mexico, and the West India Islands. The larger proportion of these varieties from the West Indies may be regarded as more closely related to our original Cuban strains. In the earlier years of the crossings, the conditions of weather were not propitious for pollen transfers, and it was found to be largely a matter of luck whether the seed set or not. In fact, it was beginning to be thought by us that the climate was not favorable to this line of experimenting. But in spite of bad weather, Mr. Robert M. Grey, the Superintendent in charge of the Station, succeeded in securing a fair number of desirable crosses. These seedlings have been transplanted into cane ground, and tests have been made of the content of sugar. Experiments show that the "Amber Cane" is still as good as any of the new varieties of our earlier series.

The last seasons have been better for the experimental work, being wholly exceptional in the recent annals of Cuban climate. Mr. Grey has been able to take advantage of the anomalous conditions and has succeeded far beyond our most hopeful expectations in obtaining new varieties. We now have at the Station about seven hundred sorts of cane seedlings, of the most varied parentage. It is believed that among this large number will be some which

will have a larger content of sugar and at the same time possess good powers of resistance to untoward influences. It is interesting to note that "Sereh" is not noted at the Station or on the Estate. Since it is the policy of the Station to place at the service of the Cubans the results of these experiments, improved varieties will be described at an early day.

Plants of various species which were brought by Mr. C. G. Pringle from Mexico direct to Cuba a few years ago and set out at once in the grounds of the Station, have done well with the exception of a few which were destroyed in a freshet which injured a part of our grounds. Most of them are now well established as stocks for experimental purposes.

During the past winter, Mr. Robert Cameron, Head Gardener of the Garden at Cambridge, made a long journey in the West Indies to secure certain fresh specimens of desirable economic plants for the Cuban Station. These have reached the grounds in good condition, and are nearly ready for crossing. To meet the demands for a wider range of soil for these new plants, additions have lately been made to the land used for study, and it is already found that our range of plants can now be materially increased. We have about all the sorts of soil and the kinds of exposure needed for our purposes. G. L. G.

19. *Plant Response as a means of Physiological Investigation;* by JAGADIS CHUNDER BOSE, M.A., D.Sc., Professor, Presidency College, Calcutta (Longmans, Green and Co., London, New York, and Bombay, 1906).—This volume of more than 700 pages is a direct outgrowth of a previous work by the same author, entitled, "Response in the Living and Non-living," published in 1902. The first nine chapters in the earlier treatise were devoted to electric response, and response in plants, while the remainder of the work was given up to a consideration of response in inorganic matters. A great deal of that work was so interesting that it almost compelled a continuance of investigation along the same lines.

In the present volume the author attempts to prove by the use of extremely delicate multiplying apparatus, by which slight movements are increased many fold, that even those parts of living plants which have not hitherto been seen in motion possess a considerable power of response to external stimulation. The types of multipliers are for the most part unlike those previously employed in vegetable physiology, and, therefore, the paths struck out by the investigator are generally new. Whether the paths lead directly to the conclusions which the author adopts, must remain an open question until his researches have been many times repeated by others. But it may be unhesitatingly said that a careful reader of the present volume must be impressed by the ingenuity of device and the delicacy of manipulation obvious throughout the whole of the experimenting, and, further, one is struck by the apparent truthfulness of all the records. Assuming that the instruments work exactly as

described, it is difficult to reach conclusions which differ materially from those stated by Professor Bose.

The author has undertaken to show that the plant is a machine, the movements of which in response to external stimuli are "reducible to a fundamental unity of reaction." He says, "In analysing plant-movements the greatest complexity arises from the confusion of effects due to internal energy and external stimulus respectively. I have however been able to discriminate the characteristic expressions of these two factors and thus to disentangle the complex phenomena which result from their combined action. Another very obscure problem is found in the nature of so-called spontaneous or autonomous movements. By the discovery, however, of multiple response, and by the continuity which I have been able to establish as existing between multiple and autonomous responses, it has been found possible to demonstrate that there are, strictly speaking, no spontaneous movements, those being known by this name being really due to external stimulus previously absorbed by the organism. Thus all the experiments have tended to show that the phenomenon of life does not, as such, connote any intrusion into the realm of the organic of a force which would interfere with that law of the Conservation of Energy which is known to hold good in the inorganic world. The elucidation of the fact that such varied and obscure phenomena in the life processes in the plant, as, for instance, growth and the ascent of sap, are fundamentally due to the same excitatory reactions as are seen otherwise exemplified in the simple mechanical response now familiar to us, constituted a further result which, at the outset of the investigation, was little to be foreseen. It has been shown finally that there is no physiological response given by the most highly organised animal tissue that is not also to be met with in the plant."

In a further notice an analysis will be made of some of the chapters: the present is simply to call attention to the general character of a very suggestive work. G. L. G.

20. *A Monograph of the British Desmidiaceae;* by W. West and G. S. West. Vol. II, pp. 204; 32 colored plates. London, 1905 (printed for the Ray Society).—The first volume of this important monograph, published in 1904, has already been reviewed in this Journal (xviii, 473). The second volume maintains the high standard set for it by the first and continues the description of species. Only three genera receive treatment; namely, Euastrum, with 46 species, Micrasterias, with 18 species, and Cosmarium, with 50 species. These genera include some of the most beautiful of the Desmids, and all three have a very wide geographical distribution. Of the species here described and figured nearly four-fifths have already been recorded from the United States. A. W. E.

21. *Die Pflanzenfabel in der Weltliteratur;* by Aug. Wünsche. Pp. 184. Akademischer Verlag für Kunst und Wissenschaft, Leipzig and Vienna, 1905.—The various fables in which plants

play an important part are discussed, with special reference to those found in the literature of Germany. The work is of literary rather than of scientific interest. A. W. E.

III. Miscellaneous Scientific Intelligence.

1. *Die Bahnbestimmung der Himmelskörper;* von Julius Bauschinger. Pp. 653, with 84 figures. Leipzig, 1906 (Wilhelm Engelmann).—The present volume is of particular interest since, coming from the hands of the able director of the Berlin Jahrbuch and Computation-bureau, the opportunities for practical testing of the methods have been unsurpassed. Also since the date of Watson's treatise of some 40 years and that of Oppolzer of some 20 years ago, which may be said to have covered the field of comet and asteroid orbit-computation at their epoch, and that of the less comprehensive but valuable works of Klinkerfues, Frischauf,* Moulton and others, a number of important contributions to this branch have been made. An especially interesting feature of Dr. Bauschinger's work are the historical sketches of the various phases of the problem.

The treatise is divided into seven parts, the first three of which treat of the coördinates, the heliocentrics and the geocentric motion of a body moving about the sun according to Kepler's laws.

Part four gives the solution of the problem of a first orbit and it is noteworthy to find that both for an ellipse from three observed positions and a parabola the methods presented in detail are substantially the Gauss-Encke and Gauss-Hansen for the former and the Lambert-Olbers-Gauss for the latter. The remarkable formulae of Gibbs, which are probably the most striking contribution of late years to the domain of orbit-computation, are briefly considered with modifications of Gibbs' original somewhat involved method; and reference is made to the ingenious methods of Weiss, Fabritius and others. For the exceptional case where four observations are requisite an expeditious method of the author is presented. The so-called direct methods, where three or any number of observations may be used, are briefly treated; the Laplace-Bruns method alone is given in full and reference only made to the work of Harzer, Leuschner and others.

Part five comprises the determination of a definitive orbit from all available observations by the method of least squares, and part six the theory of special perturbations, examples being given for the variation of constants and the perturbations in rectangular coördinates.

In part seven are found methods for orbits of meteors, satellites and binary stars.

Dr. Bauschinger has already published a collection of numerical tables for use in theoretical astronomy and the two works

* To which an appendix with an application of Gibbs' principle has lately been issued by the same publishers.

together may be confidently recommended as a complete and practical presentation of the present status of orbit determination.

W. L. E.

2. *Report of the United States National Museum under the direction of the Smithsonian Institution for the year ending June 30, 1904.* Pp. xvi, 780, with 66 plates and 142 text-figures. Washington, 1906.—The Assistant Secretary of the Smithsonian Institution, Mr. Richard Rathbun, gives in this volume a report of the present condition of the U. S. National Museum and the work done during the year named. This is supplemented by the reports of the Head Curators. Part II contains the History of American Geology by George P. Merrill, noticed on a preceding page (p. 467); also a description of the Howland Collection of Buddhist Religious Art in the Museum by I. M. Casanowicz, and of Flint Implements of the Fayum, Egypt, by H. W. Seton-Karr.

3. *The Dynamics of Living Matter;* by JACQUES LOEB. Pp. 233. New York, 1906. (The Columbia University Press, The Macmillan Company, Agents.)—The scope of this volume is clearly indicated by the introductory paragraph: "In these lectures we shall consider living organisms as chemical machines, consisting essentially of colloidal material, which possess the peculiarities of automatically developing, preserving, and reproducing themselves. The fact that the machines which can be created by man do not possess the power of automatic development, self-preservation, and reproduction constitutes for the present a fundamental difference between living machines and artificial machines. We must, however, admit that nothing contradicts the possibility that the artificial production of living matter may one day be accomplished. It is the purpose of these lectures to state to what extent we are able to control the phenomena of development, self-preservation, and reproduction."

The present book presents the same broad views of the fundamental problems of physiology as have dominated the earlier "Studies in General Physiology" and the "Comparative Physiology of the Brain" by the same author. It is impossible to read these comprehensive records, characterized as they are by the author's remarkable familiarity with the literature of comparative physiology and his unusual personal experience as an investigator, without immediate profit. His treatment of biological themes is as original as it is unique. The point of view may be unusual at times, but it is always suggestive. One may not always follow Professor Loeb with an enthusiasm equal to that with which some of his more radical views are championed. Nevertheless in such cases the critical reader will usually find that the pursuit of the new ideas stimulates, even if it fails to convince him.

To help in the construction of a mental picture of the make-up of living matter, Loeb has drawn aid from the newer discoveries of physical and chemical science. The topics: general chemistry of life phenomena, the general physical constitution of living matter, the rôle of electrolytes, tropisms, fertilization, heredity,

and regeneration will serve to indicate the range of the lectures. The chapters on tropisms, for example, are of exceptional general interest and show how trenchant the author's critique may become at times. In discussing a theme upon which so widely divergent views are held, he wisely says: "The more fertile a principle is, the more we can afford to be conservative in applying it." (p. 159.) Loeb mountains that the tropisms and tropism-like reactions will one day form the main contents of a scientific psychology of lower forms. The subject of fertilization, as might be anticipated, is discussed in a comprehensive way. Indeed the writer is far more successful in the treatment of general topics of this character than of more specific problems like those of secretion, for instance. The volume will be fruitful in awakening further interest in general physiology, and cannot fail to add to the author's influence on the progress of biological research and teaching in America. L. B. M.

4. *Carnegie Institution of Washington.*—The following are recent publications of the Carnegie Institution:

No. 9.—The Collected Mathematical Works of George William Hill. Volume II, pp. 339. Containing memoirs Nos. 37–49. Volume III, pp. 577. Memoir No. 50, A new theory of Jupiter and Saturn.

No. 40.—The Nucleation of the Uncontaminated Atmosphere; by CARL BARUS. Pp. xii, 152; with 104 figures.

5. *Brooklyn Institute of Arts and Sciences.*—Science Bulletin, vol. I, No. 7 (pp. 141–186) contains two papers by Chas. Schaeffer. The first describes some new Coleoptera from Brownsville, Texas, with notes on species now first recorded from the United States chiefly from the Huachuca Mts., Arizona; the second paper gives a list of Bombycine moths collected in 1905 in the Huachuca Mts. A third paper by H. S. Dyar describes some new moths from Arizona.

Der Ablauf des Lebens; Grundlegung zur Exakten Biologie; von Wilhelm Fliess. Pp. 584. Leipzig und Wien, 1906.

OBITUARY.

Professor NATHANIEL S. SHALER, whose death on April 10 was announced in our last number, was born near Newport, Ky., on Feb. 20, 1841. He went to Harvard in 1859, enrolling in the Lawrence Scientific School and studying chiefly with Louis Agassiz. After receiving the degree of S.B. in 1862, he enlisted in the Fifth Kentucky Battery and saw active service in the Union army for two years. On returning to Harvard he was appointed lecturer in 1864, professor of paleontology in 1869, professor of geology in 1888, and dean of the Lawrence Scientific School in 1891. He was given the degree of LL.D. by Harvard in 1903. Shaler's lectures on geology were always popular; it is believed that he thus addressed some 7,000 students, probably a larger number than were ever taught geology by any other man. He was of marked individuality, inventiveness and activity, of

strong feelings and of unusually wide interests. The department of geology at Harvard flourished under his leadership, increasing greatly in number of teachers, subjects taught, students enrolled and equipment. The department of mining and metallurgy was developed under his initiative. The Scientific School was rehabilitated by his vigilant care as dean, and at the time of his death he saw the beginning of a consummation to which he had long looked forward: the establishment of a Graduate School of Applied Science at Harvard under the endowment of his long-time friend, Gordon Mackay. Shaler was director of the Kentucky Geological Survey from 1872 to 1879, geologist of the U. S. Geological Survey for a number of years, president of the Geological Society of America in 1895; he was frequently consulted on mining enterprises in the South and West, and was a member of Topographical Survey. Highway and Gipsy Moth commissions of Massachusetts. His writings covered many phases of geology, the brachiopods of the Ohio Valley, the caverns of Kentucky, glacial phenomena in New England, the structure of the Narragansett basin, the features of sea coasts, the face of the moon. In recent years, his thoughts turned towards social problems, as illustrated in three volumes, The Individual, The Citizen, and The Neighbor, and he found entertainment in writing on the Elizabethan period in blank verse. His death was caused by pneumonia following an operation for appendicitis; it came upon him suddenly in the midst of work, his last official act being the preparation of a circular announcing the establishment of the new Graduate School of Applied Science and the associated changes in the administration of scientific work at Harvard. W. M. D.

Israel Cook Russell, Professor of Geology in the University of Michigan, died May 1st, in the 55th year of his age. His death coming in the middle of a busy life, is a blow, not only to the university which he had actively and efficiently served since his appointment in 1892, but to the science in this country which during many years he had so materially promoted by his work and publications. He was educated at New York University and Columbia College and soon became connected with the Government surveys of the West. His investigations of former Lake Lahontan, like those of Gilbert's Bonneville, produced results which have become classic in geologic literature. His explorations in Alaska and in the extreme northwestern states contributed knowledge of great interest and importance from little known regions, and laid the way for detailed investigations of the future. His interests tended largely to the physiographic side of geology, and his volumes, written in a popular way for instruction, on the volcanoes, glaciers, rivers and lakes of North America, have had a host of readers and have stimulated interest in geologic science. He also made the Triassic deposits of the east a field of special study, and his volume on the Newark formation is a standard work of reference on this subject. His genial disposition endeared him to all who knew him and he will be mourned by many friends. L. V. P.

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